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Develop, Evaluate and Validate Continuous Emission Monitors for Designated Hazardous Pollutants

Midwest Research Inst., Kansas City, MO

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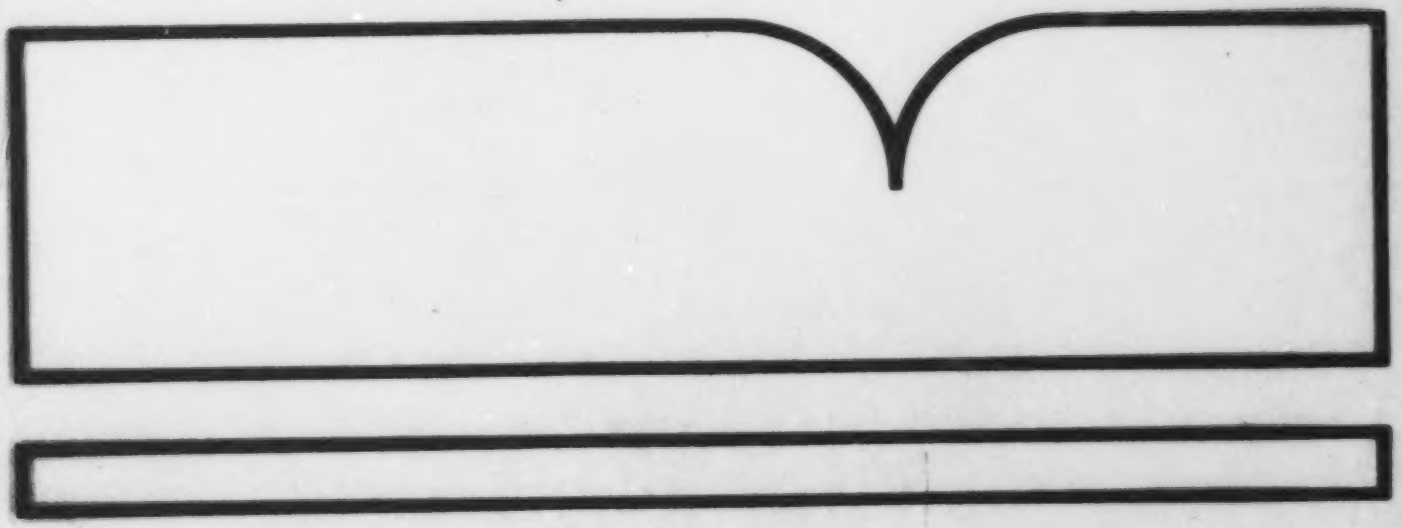
Research Triangle Park, NC

May 85



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DEVELOP, EVALUATE AND VALIDATE CONTINUOUS EMISSION MONITORS FOR DESIGNATED HAZARDOUS POLLUTANTS

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EPA Contract No. 68-02-3770

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The objectives of this project are to assess the state of the art of continuous emission monitoring of vinyl chloride monomer (VCM) and to conduct actual experiments to evaluate two monitors in laboratory and in a six-month field testing program.

A process GC with flame ionization detector and a photoionization detector were used during this study. Three one-week EPA Method 106 tests were conducted during the six-month field testing program to measure the relative accuracies of the monitors.

The precisions of both types of detectors all were in the 1% range when evaluated in laboratory.

The relative accuracies for both types of detectors were <10% for VCM concentration between 2 to 10 ppm.

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PREFACE

This report was prepared by Midwest Research Institute (MRI) in response to the requirements for Environmental Protection Agency (EPA) Contract No. 68-02-3770.

The project was under the technical supervision of Mr. Fred Bergman, Program Manager, Field Programs Section of the Environmental Systems Department. Dr. George Scheil served as project leader with assistance from Ms. Marilyn Gabriel and Mr. Kent Hall. Ms. Carol Green supervised the quality assurance activities. The EPA project officer was Dr. Jimmy C. Pau.

Approved for:

MIDWEST RESEARCH INSTITUTE

M. P. Schrag, Director
Environmental Systems Department

December 1984

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SECTION 1.0

INTRODUCTION

This report describes a project conducted by Midwest Research Institute (MRI) for the U.S. Environmental Protection Agency (EPA) to provide background information for the development of performance specifications for continuous analyzers for hazardous organic pollutants. The project had two purposes: to assess the state of the art of continuous monitoring for vinyl chloride (VC) and to evaluate the performance of two different analyzers over a period of 6 months. One of the analyzers was to be furnished by the sponsor.

The assessment phase consisted of a review of currently available VC analyzers. Continuous emission monitors for VC were reviewed that were based upon six different analysis methods. Only analyzer systems using gas chromatography (GC), however, met all the criteria for use in monitoring process streams at VC monomer plants. The original EPA-furnished analyzer was a GC, an Applied Automation Model 102 process GC with a flame ionization detector (FID) and an analog peak integrator. A GC based upon a photoionization detector (PID) and a digital integrator was considered as the second analyzer. However, the cost of a complete second GC exceeded the available funding. Because both types of detectors and both integrators are compatible, the original EPA-furnished process GC analyzer was modified for dual detectors (flame ionization and photoionization) and dual integrators (analog and digital) and was selected as the only analyzer for further testing.

After assembling the analyzer system, a series of laboratory tests was conducted. These included interference tests, a critical variable matrix test, and a 1-month operating test with the complete system operating under simulated field conditions. Several further improvements were made during this phase of the project.

Finally, the analyzer system was installed at a VC monomer plant and operated for 6 months. Data on system availability, calibration drift, precision and comparative readings for the different detectors and integrators were recorded during this period. Analyzer bias was evaluated using data collected during three 1-week equivalence tests. EPA Method 106 was considered as the reference method. Despite several problems, the analyzer and the remote data access systems successfully completed the test period. Both detectors and both integrators produced similar concentration data during the test period.

Appendix A includes daily summary data during the test period. Appendix B contains the results of the Method 106 equivalence test. The statistical terms used in the report are defined in Appendix C.

SECTION 2.0

CONCLUSIONS AND RECOMMENDATIONS

Both detectors (FID and PID) and both integrators (analog and digital) successfully completed 6 months of operation under field conditions, including exposure to upper and lower extremes of temperature and occasional assault by corrosive gases and liquids. Although differences were observable, in general, both types of detectors and integrators produced similar data during this study. None of the problems were catastrophic. Most of the problems encountered were related to the primary weaknesses of each system type. Both detectors and both integrators are commercially available units. To minimize costs a dedicated digital integrator was not used. The digital integration was performed as a BASIC subroutine on the general purpose microcomputer used for data logging. Specific conclusions were:

1. All four detector-integrator combinations teste during this study agree to within ± 0.02 ppm VC averaged over the full 6-month period. The difference standard deviations for simultaneous paired readings were generally within 0.1 to 0.3 ppm VC.

2. The biases of all four detector-integrator combinations, compared to EPA Method 106, was < 10% of the VC concentration for 90% of the runs between 2 to 10 ppm. At VC concentrations of < 2 ppm the bias was > 10% of the VC concentration for 90% of the runs. The results of 13 of the 60 runs were excluded because of process upsets.

3. An FID is a reliable and well characterized GC detector which responds to most organic compounds. It requires constant supplies of hydrogen and air of consistent quality. A significant amount of time could have been saved in this study if the particular unit used had had an automatic reignitor, a feature which is available on some instruments.

4. The PID, a much newer detector than the FID, demonstrated good reliability during the test, although detector life may be a problem in applications which require maximum sensitivity. The PID avoided the problems of flame gas supply and has better recovery from utilities failure with its all electronic design. Although the PID has better ultimate sensitivity than the FID, this applies to only certain compounds. Also, the ability to change source lamp excitation wavelength allowed the PID to rejct some of the potential VC interfering compounds.

5. Both integrators showed bias (compared to EPA Method 106) and poor precision when measuring VC concentrations of < 2 ppm. This may have little effect for enforcement actions. However, if full range data are needed, the

concentration of the second (50% of full-scale) calibration standard should be reduced to 10%. Poor performance in the lower concentrations frequently provides warning of problems because successful measurement of small GC peaks requires good instrument performance.

6. The analog integrator with preset integration window(s) balanced its superior ruggedness against its limited ability to handle peak retention time changes or sloping baselines. It had no component failures or malfunctions but was easily confused by baseline shifts, and close eluting peaks could not be resolved.

7. The computer hardware used for digital integration suffered slightly because it was not specifically designed for unattended data collection. Digital computers require a more protective environment than an analog system although good electrical isolation and high reliability (military grade) components can eliminate most of this limitation. For unattended operation such a system requires reset functions such as those used successfully in the analog interface and modem subsystems to halt runaway microprocessors, which was the fatal flaw in the Action Instruments BC-2 system originally selected. The integration program used in this study responded well to peak drift and sloping baselines but would have better small peak response with a larger baseline search offset to prevent premature cutoff of the integration. A wide variety of integration techniques are available for digital systems. The relatively sophisticated routines used in laboratory integrators tend to suffer in automatic applications due to the great difficulty of testing for all possible conditions. The preliminary laboratory tests clearly demonstrated the value of keeping the system simple.

Based upon the above conclusions and other results of this study, the recommendations for further study are:

1. Use calibration gases of 0, 10, and 90% of the analyzer's full scale response. A secondary calibration gas of 50% full scale does not have sufficient separation from the 90% (span) gas to detect nonlinearity or degrading analyzer performance.

2. Improve the low level response of the digital integration by increasing the minimum integration peak width to equal the peak width observed while measuring the 90% of full scale standard.

3. Conduct further studies to determine the cause of the analyzer nonlinearity which developed during the field test. The primary possibilities are either an improper choice of column (Porasil C) or gradual degradation of the columns with extended use.

4. Conduct further studies to determine the cause of the high noise levels which usually coincided with high ambient temperatures. A power supply ground loop in the digital computer appears to be a factor but other components could be involved as well.

5. Investigate alternative detector-integrator arrangements which either minimize the distance for transmission of low level detector signals or increase signal strengths.

SECTION 3.0

DISCUSSION OF RESULTS

In this section, which discusses the results of the study, selection of the two analyzers for the study is described first, followed by the results of the laboratory and field tests.

3.1 ANALYZER SELECTION

An existing process GC (Applied Automation Model 102) was furnished by the EPA for evaluation. This unit had a 30-cm backflush column of 1/16-in. stainless steel tubing packed with n-octane Durapak for removing heavy organics, followed by a 30-cm analytical column of 1/16-in. stainless steel tubing packed with Porasil C to separate VC from other light organics; a flame ionization detector (FID); and an analog preset time window integrator. The system also has a sample conditioning section, gas sampling valve, and control system for automatic, repetitive sampling and analysis.

A review of currently available instruments was conducted to select a possible second analyzer. Table 1 lists several methods commercially used for continuous monitoring of VC. Most of these methods respond to broad classes of organics rather than to specific compounds or are designed for use in ambient air, not process streams. Only gas chromatography has the necessary sensitivity and selectivity for measuring VC near the current 10 ppm standard in process streams in the presence of significant amounts of ethylene dichloride and other organics. A growing number of VC analyzers are using PIDs instead of flame ionization detectors, and there is some use of electron capture detectors. Also, digital integrators are gradually replacing analog systems for peak analysis, and there is occasional use of measurements for peak height instead of peak area.

A process GC with a PID and a digital integrator was selected as the method for a second analyzer. The PID has potentially better sensitivity to VC than the FID and has little response to potential interferences such as ethyl chloride. Moreover, the PID, unlike the FID, requires no special supply gases, and the PID is not as easily poisoned as an electron capture detector. Peak height measurements suffer from nonlinearity problems whereas digital integration matches the growing use of microprocessor-controlled analyzers.

Because the cost of purchasing a second process GC exceeded the available project funds, a study of alternatives was necessary. More than half the cost of a second process GC would be used to duplicate the valves, column, and other basic hardware to support a detector and integrator. Since the PID is a nondestructive detector, an in-line PID could be added to the existing

EPA system. A simple switching relay would allow either integrator to be selected. Adding a PID and digital integrator to the existing system thus saved considerable money and had the added advantage of allowing better discrimination of any differences between the types of detectors and integrators. Thus, a single analyzer system with dual detectors and integrators was assembled. The added modules were a Model PI52 PID with a 10.2 eV lamp (HNU Systems, Inc.) and a Model BC-2 instrument control computer (Action Instruments).

Figures 1 and 2 show the original design with two analyzers and the revised design, respectively. The test design for the project included a calibrator that substituted calibration gases of 0, 5, and 9 ppm VC for the sample gas once each day. A digital data logger was designed by MRI to provide a phone modem link to transmit data back to MRI on request, with backup records on a printed log and magnetic tape. The system operated unattended; only a twice-monthly supply visit was needed unless the phone link checks indicated problems with the system.

3.2 LABORATORY TESTS

Before the 6-month field test was begun, a series of experiments was completed in the laboratory to determine optimum operating conditions, analyzer sensitivity to the instrument control parameters, and possible interferences. The typical VC reactor product gas as sampled contained significant concentrations of ethylene and ethylene dichloride, as well as VC, and smaller amounts of other light chlorinated hydrocarbons. Small amounts of chlorine and hydrochloric acid were also present which required the replacement of all stainless steel in the sample conditioning system with Monel, Teflon, or Kynar parts. Since the chromatographic section and detectors were exposed to only dried sample gas, they were left unchanged. Test mixtures of the compounds at about 10 ppm (Table 2) and similar concentrations of VC were prepared using permeation tubes and sampled by the process GC. The backflush column rejected most of the compounds, and the positive interferences with shorter retention times than VC had at least partial separation. Although the FID response to chloromethane was similar to the VC response, the PID response was less than 1% of the equivalent VC response.

During preliminary testing the BC-2 digital integrator system developed severe problems because it had poor isolation from electrical noise. The computer had nonrecoverable system crashes about once an hour and the probable cost of remedial action was excessive. Fortunately the MRI data logger, based upon an Epson HX-20 briefcase computer matched with a Wintek MCS analog interface, was functioning well in the same environment. The excellent line isolation of a Nicad-powered computer together with the optical isolation and reset capabilities of the Wintek system allowed reliable recovery from noise spikes. The logger system could measure the detector signals with the addition of a simple amplifier and had sufficient idle time during each analysis cycle to perform the necessary peak integration. Therefore, the logger was reprogrammed to perform the digital integration task as well as to log the results and communicate with MRI.

The reliability of this modified system proved satisfactory, and the matrix test of control variables was conducted. Each variable was tested by

measuring a VC standard gas at the optimum condition (defined as the center of the stable operating range) and then at reasonable steps higher and lower than the optimum.

Two variables (controlling the integration window) affected only the analog integrator, and four variables (controlling peak baseline sensing and noise factors) affected only digital integration. Two other variables (controlling air/fuel ratio) affected only the FID. The HNU detector had no unique variables. The five remaining variables (controlling valve timing and the GC columns) affected all methods.

The results of the laboratory tests are summarized in Table 3. The effect of each variable is classified as follows:

None - change < 1 σ
Weak - change 1 to 2σ
Moderate - change 2 to 3σ
Strong - change > 3σ

Indications of moderate or strong effects also showed the apparent change in concentration of the standard mixture in percent (measuring from optimum to either limit).

All tests were conducted with a 10 ppm vinyl chloride in nitrogen standard connected to the sample inlet. Each variable was tested independently at a setting lower and higher than the optimum value while all other variables were held constant. The optimum settings had been determined earlier. The variables test indicated that the initial air/fuel ratio specified for the FID by the manufacturer was fuel rich. New optimum values for air and hydrogen feeds were established before proceeding with the test.

The four method combinations tested were:

PA - photoionization detector by analog integration,
s.d. ~ 0.03 ppm or 0.3%

FA - flame ionization detector by analog integration,
s.d. ~ 0.10 ppm or 1%

PD - photoionization detector by digital integration,
s.d. ~ 0.10 ppm or 1%

FD - flame ionization detector by digital integration,
s.d. ~ 0.10 ppm or 1%

The superior precision for PA allowed smaller effects to be identified than with the other combinations.

Of the variables which had at least a moderate effect, only the carrier supply pressure was observed to approach the test limits. This could be checked by monitoring the peak retention times measured by the digital integrator. The other variables were normally well controlled or could not be

set to less critical values because of fatal peak resolution problems when interfering compounds were present. Since most of the strong effect variables were general in effect, the stability of the PA results indicates that these variables were, in fact, well controlled.

The analog integrator measures the baseline at a fixed time just before the VC peak and integrates any signal above that baseline until the fixed stop time. Since the start and stop times are fixed with respect to sample injection, changes in the VC retention time may cause loss of part or all of the peak if the peak window is too narrow.

The two detectors measure the same peak at slightly different times, therefore, a change in the integration windows or the retention time will affect each detector differently. The digital integrator program first scans the chromatogram for the peak maximum nearest the expected time of the VC peak, jumps forward by a preset offset to begin searching for a level baseline at the start of the peak, performs a similar operation to find the end of the peak, and subtracts the average baseline from the area under the peak.

Searching for the VC peak maximum corrects for normal drift in retention time. Limits for the peak maximum search are necessary to prevent the program from locking onto an interfering peak or continuing the search to one end of the chromatogram if no VC peak is present.

The program searches for a section of nine consecutive points (the sampling rate is 10 points per second) with minimum slope. The slope must be less than a preset level and the scan continues beyond the apparent minimum for several points to verify that the true minimum was found. The use of a level baseline instead of a constant slope baseline avoids premature stops to the integration on the rather smooth leading and trailing edges.

The baseline search offsets are used to speed up the integration process because a real peak will have a known minimum width and because the start and end of very small peaks are difficult to separate from normal baseline drift. The offsets are different because real peaks exhibit tailing which causes the distance from leading edge to maximum to be shorter than the distance from the maximum to the trailing edge. Although the PID has no readily controlled unique variables, the FID is sensitive to changes in the flame hydrogen supply pressure and thus to its flow rate.

3.3 FIELD TEST

While the complete instrument system was undergoing a 1-month reliability test in the laboratory under simulated field conditions, final arrangements for the field installation were being completed. The primary difficulty in selecting a test site was that all the plants contacted had gas streams which were either much less than 1 ppm VC or at concentrations of at least 1,000 ppm VC. The analyzer was finally installed on a reactor offgas stream with a nitrogen dilution tee to bring the VC concentration to within the 1 to 10 ppm range needed for equivalence testing. A polypropylene sample line was used to connect the process tap to the analyzer trailer about 400 ft (120 m) away. The line was unheated because the process stream was at ambient

temperature and the sample was diluted (~ 1:1000) with nitrogen. Thus, the ratio of VC to the interfering compounds was maintained the same as in the VC reactor gas, while allowing the sample concentration to be controlled at the desired 1 to 10 ppm range.

The field test had two main objectives: (a) to obtain long-term analyzer reliability and stability data over a 6-month period and (b) to complete three equivalence tests during the 1st, 13th, and 26th weeks of operation.

3.3.1 Long-Term Reliability and Stability Data

The primary field record was the data transmitted by modem approximately once each day. Each data transfer included the 51 hr of data immediately preceding the phone call. Thus to obtain a complete phone data record, data had to be transferred every other day. Missing blocks of phone data were filled by reading the logger data tapes which are returned to MRI every 2 weeks. If both of the computer readable data records were unusable, the final recourse was to manually key in data from the printer tape which was also available every 2 weeks. Except for the first week when the tape backup was used, all test data are from the primary (modem) record. The modem record was not available the 1st week, because the phone line installation was slower than anticipated. The backup records were periodically compared with the primary data to verify data quality.

During operation, each phone data block was screened immediately for major problems and stored on computer disk files. Approximately once each week the accumulated data were processed into final form and once each month a set of summary statistics were compiled for that calendar month.

The data processing procedure was as follows. During each analyzer cycle (about 2 min duration), two of the four detector-integrator combinations, either the FD and PA channels or the PD and FA channels, were read alternately. A time and date stamp was also present every fifteenth cycle. A 1-hr calibration check was also made daily using cylinder gases of 0, 5, and 10 ppm VC.

The calibration period was first located with operator assistance, and a linear least square fit of all stable calibration readings was calculated for processing the next 24 hr of data. The paired readings were then combined into quads containing one reading for each of the four channels. The averages for each channel were calculated to measure biases from one channel to another, and the difference standard deviations of the FD-PA and PD-FA simultaneous paired readings were calculated as handy indicators of the precision of the methods. The FA combination of the original analyzer before modification was used as the reference channel to measure method bias. The daily sets were also checked for quads which contained FD-PA or PD-FA differential readings which exceeded four times the respective standard deviations. This 4 α value was selected as an appropriate compromise to allow most of the data to be retained for analysis yet exclude any extreme observations. Quads which exceeded the limit were removed before calculating the final statistics.

The daily files accompany this report on two double-sided MS-DOS 2.0 data disks readable as BASIC files. Tables showing daily and monthly statistics, as well as data from the final laboratory performance test, form Appendix A.

Data recovery efficiency is shown in Figure 3. The over-range readings were caused by changes within the host monomer plant which upset the sample dilution ratio. Data recovery for November and December was affected by bad weather which produced repeated flameouts when the plant instrument air supply failed. During February the sample gas input overloads were so severe that the integrator skipped cycles. During April the data logger malfunctioned when a power supply in the data logger analog interface failed. The power supply was successfully replaced. A chronology of the major events during the test is shown in Table 4. Overall, the analyzer system recovered 77% of the possible data quads. One percent was rejected as outliers and 10% of the data was over-range with 67% of the possible data being usable for further analysis. Most of the data losses occurred during the first 3 months after the flameouts and column changes. Data recovery during the last half of the test was near 90%.

Figure 4 shows monthly zero drift of the calibration data plots, and Figure 5 shows the corresponding drift in slope of the least square fits. Except for a sharp change during February, analyzer drift was gradual and small on all channels. The cause of the poor performance in February was the series of very high VC concentration episodes when the process header pressure rose enough to drastically reduce the nitrogen dilution ratio. The VC concentration in the sample line was high enough during these upsets that minor leakage in the sampling/calibration mode valve altered the calibration gas concentrations going into the analyzer.

Finally, Figure 6 shows the monthly average bias and precision results for the test period. The number shown below each set of error bars is the average VC concentration for that month. The different detector-integrator combinations show little overall bias with reference to the analyzer's original FID with analog integration. The overall bias is less than 0.02 ppm on all three channels. Standard deviations varied from 0.1 ppm to 0.3 ppm as monthly averages except during February which was affected by the analyzer overloads.

3.3.2 Equivalence Tests

The three equivalence tests used EPA Method 106 (Federal Register, 47, 39168, September 7, 1982) as the reference method. Each Method 106 test lasted 60 min. The analyzer readings during the sampling period were averaged. A separate measurement was made at the end of each run by connecting the integrated Method 106 bag to the analyzer sample inlet.

The published procedure was used with one exception. Since the sample stream was under positive pressure, a metering valve was installed on the inlet of the 40-L Tedlar sample bag. The bag was filled at a constant rate of 400 mL/min, and the flow rate was measured by a rotameter connected to the outlet of the sample bag enclosure. The sampling pump was used only to empty

the Tedlar bag between runs and to pull the sample bag gas through the test analyzer after the end of each test run.

The Method 106 measurements were made on a Varian 1400 GC with a FID and a Carle heated gas sampling valve (5 mL sample loop) operating at 110°C. The first five runs used a 2-m column of 1/8-in. nickel tubing packed with 80/100 mesh Chromosorb 102 operating at 100°C. To obtain better separation, a 1-m column of 1/8-in. stainless steel tubing packed with 100/120 mesh Porapak S was added after the primary column with the combined columns operated at 120°C. Each sample and standard was analyzed at least three times using peak areas measured by digital integration. The results of all three analyses were used unless one reading failed the 5% Method 106 requirement of reproducibility of successive injections.

The analyzer was calibrated with 0, 5, and 10 ppm VC standards. The Method 106 standards were separate cylinders of 1, 10, and 25 ppm VC. The 25 ppm Method 106 standard was not used during the first series because none of the samples exceeded the concentration of the 10-ppm standard. Method 106 standards were run at the beginning and end of each day.

Figure 7 shows linear regression lines from the 20, 1-hr equivalence tests in the first test series (more detailed tables are given in Appendix B). All four detector-integrator channels read lower than the reference method at low concentrations. As a further check of equivalence, the Method 106 integrated bag was also connected to the analyzer sample inlet. This procedure detects differences caused by variations in the Method 106 sampling rate or sudden changes missed during the 150-sec analyzer cycle. The results from the integrated bag measurements (Figure 8) indicate the same bias pattern.

After several tests the problem was isolated to the Porasil C analytical column. The column had a short retention time for VC, but the uncoated silica was causing nonuniform adsorption. After replacing the analytical column with a Porapak Q-S column, the nonlinearity disappeared. After resetting the system timing, the analyzer operated for about 1 month before the second equivalence test series.

During the second test series the direct monitor readings (Figure 9) showed some scatter but random bias. The integrated bag readings (Figure 10) had less scatter. An examination of the individual test runs indicates that the integrated bag concentrations were biased toward the initial sample concentration due to a higher than normal flow rate during the first few minutes as the pressure within the bag enclosure stabilized.

During the third test series the direct monitor readings (Figure 11) showed strong bias with completely different regression lines, especially between the two detectors. Once again, the regression lines were better in the integrated bag readings (Figure 12). Throughout this series frequent process changes made it very difficult to maintain a steady VC concentration. During several runs some of the channels had over-range readings which forced their

exclusion from the data analysis. High ambient temperatures also caused intermittent periods of high electrical noise which led to lost readings from the digital integrator and logger. Near the end of the week the integrator noise was found to be caused primarily by a ground loop or power instability within the HX-20 when its periodic battery recharge coincided with high temperatures. Between the sudden process changes and high noise levels, few definite conclusions could be made about the third test series.

SECTION 4.0

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

4.1 PERFORMANCE AUDITS

The Quality Control Coordinator (QCC) submitted two audit gases for analysis. The gases were NBS traceable vinyl chloride, cylinder 70 (1.0115 to 0.9719 ppm as nitrogen) and cylinder 71 (10.22 to 9.82 ppm, or 10.02 ppm as nitrogen). The gases were analyzed on December 19, 1983 and January 19, 1984. The results and percent relative error, relative to the standard values are tabulated as follows:

Cylinder No.	Date	Measured Concentration (ppm)				Relative error (%)			
		PD	FD	PA	FA	PD	FD	PA	FA
70	12/19/83	0.791	0.786	0.809	0.798	-20.2	-20.7	-18.4	-19.4
70	01/19/84	0.876	1.049	0.914	0.508[a]	-11.7	+5.8	-7.8	-48.8
71	12/19/83	10.184	10.101	10.216	10.204	+1.6	+0.8	+2.6	+1.8
71	01/19/84	10.493	10.442	10.480	10.260	+4.7	+4.2	+4.6	+2.1

[a] Bad baseline.

The percent relative error of No. 70 on December 19, 1983, was considered to be out of limit (more than 10%). Corrective action was taken and the cylinders were reanalyzed on January 19, 1984. The action appeared to have corrected the nonlinearity of the analyzers. Six of the eight values were within limits. The two values out of limit were most likely due to a noisy baseline; the noise should have cleared up after the system was in operation a little longer. No further action appeared warranted at that time.

4.2 SYSTEMS AUDIT

The QCC conducted a systems audit on February 28, 1984. Section 10 of the QA Plan was verified. Nothing was observed that would affect the quality of the data. The recorder experienced occasional signal interruption and may require servicing. The integrator performance was evaluated relative to manual measurements; the percent relative errors were -7.2, -2.2, and 8.6%. The integrator appeared to be operating satisfactorily.

4.3 ADDITIONAL AUDITS

Data from October 29 to 31, 1983, was examined by the quality assurance manager (QAM). Missing data were due to program restart. The program was later corrected for an error in finding adjacent outliers.

Data from February 14, 1984, was examined by the QAM. The original tape was compared with the final printout. The tape showed skipping only when the system went out of control. Computer calculations from the first four values per quad were manually checked; the differences were due to rounding. Channels and the single outlier (greater than 4 sigma) were excluded properly. The computer program appeared to be operating satisfactorily.

Logbooks were examined by the QAM on February 22, 1984; no major problems were found.

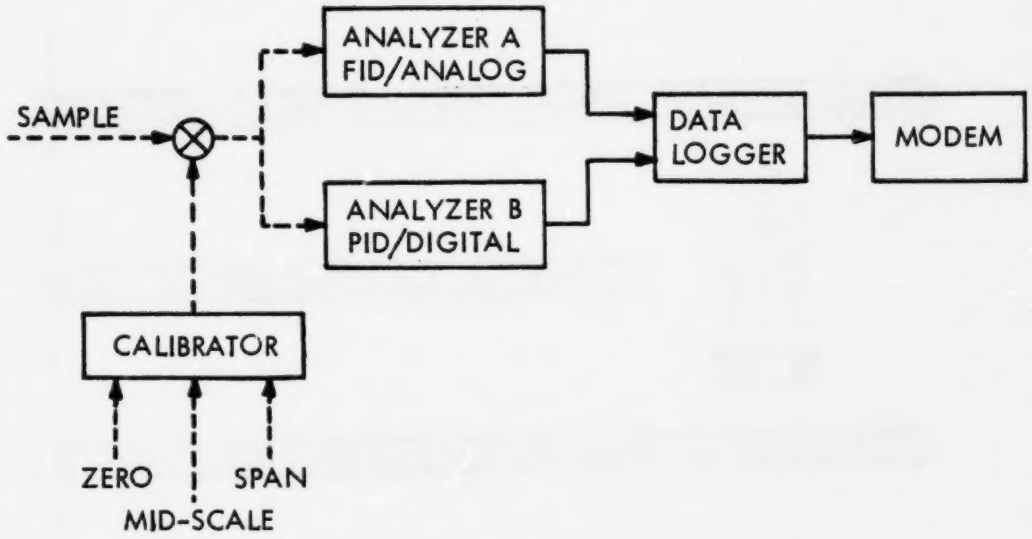

Figure 1. Original schematic of analyzer system.

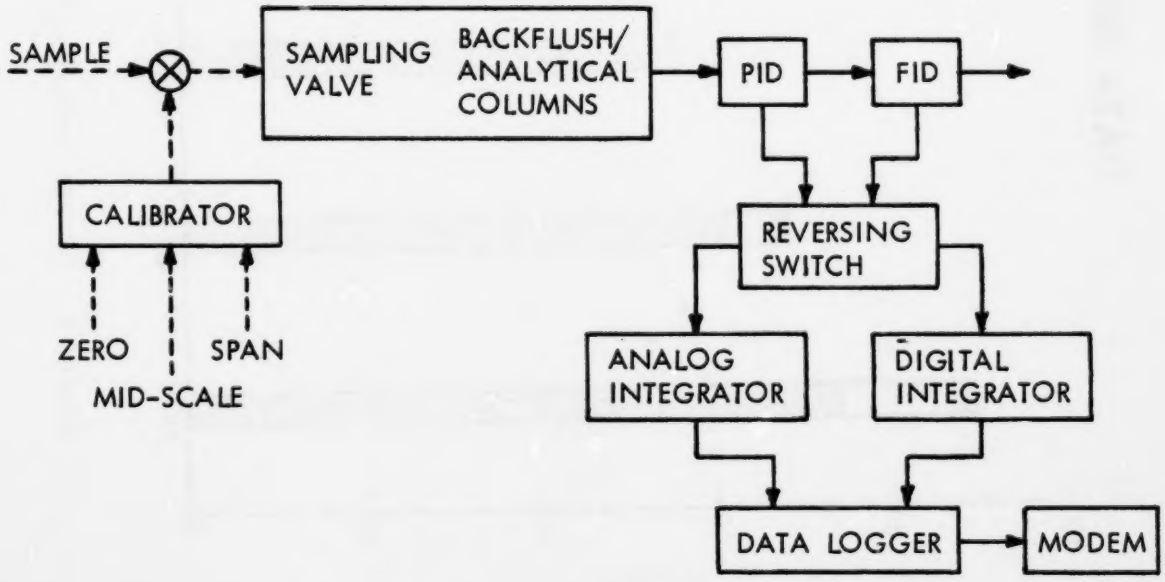

Figure 2. Revised schematic of analyzer system.

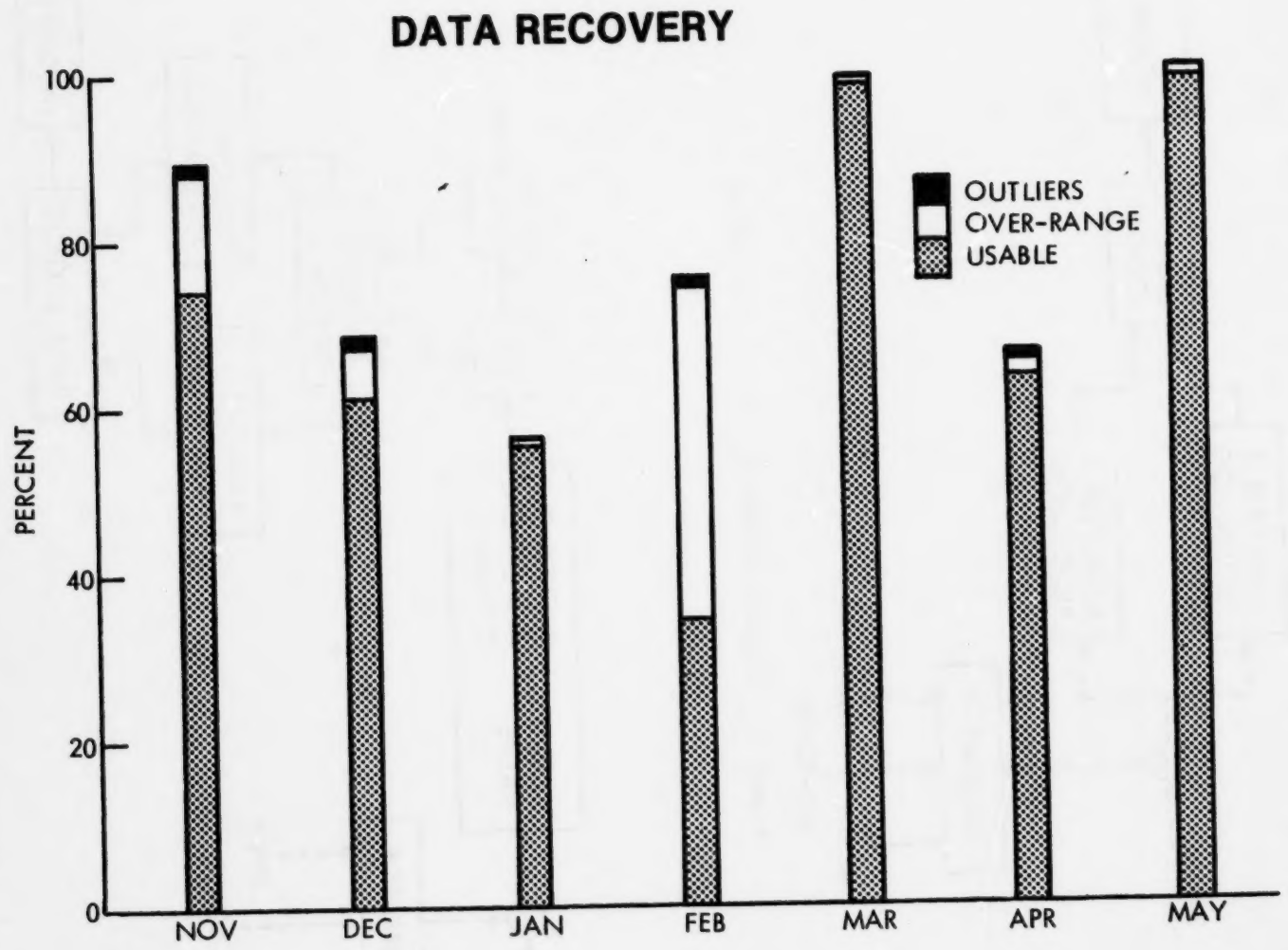

Figure 3. Average monthly data recovery of complete data sets.

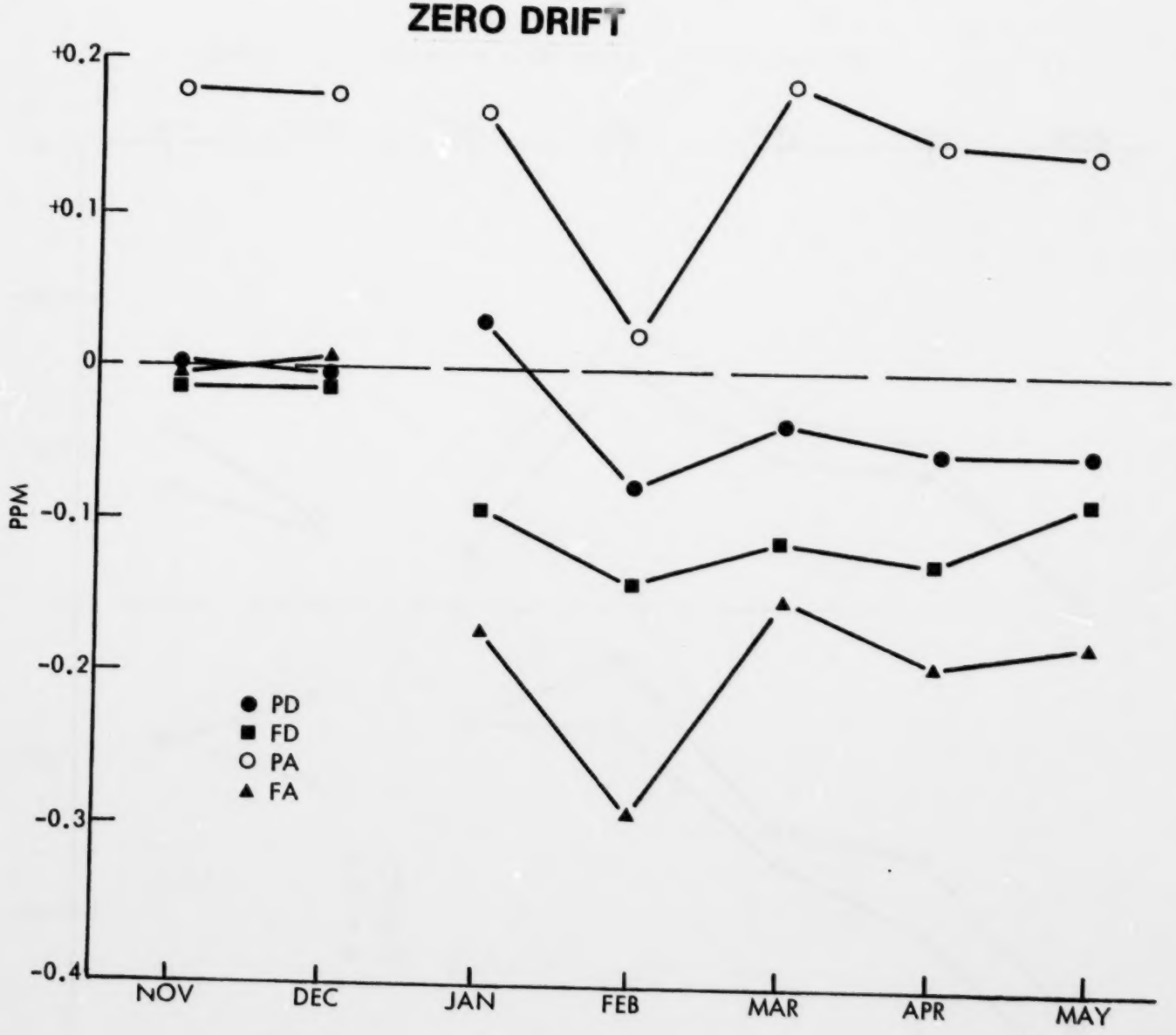

Figure 4. Calibration zero drift - monthly averages.

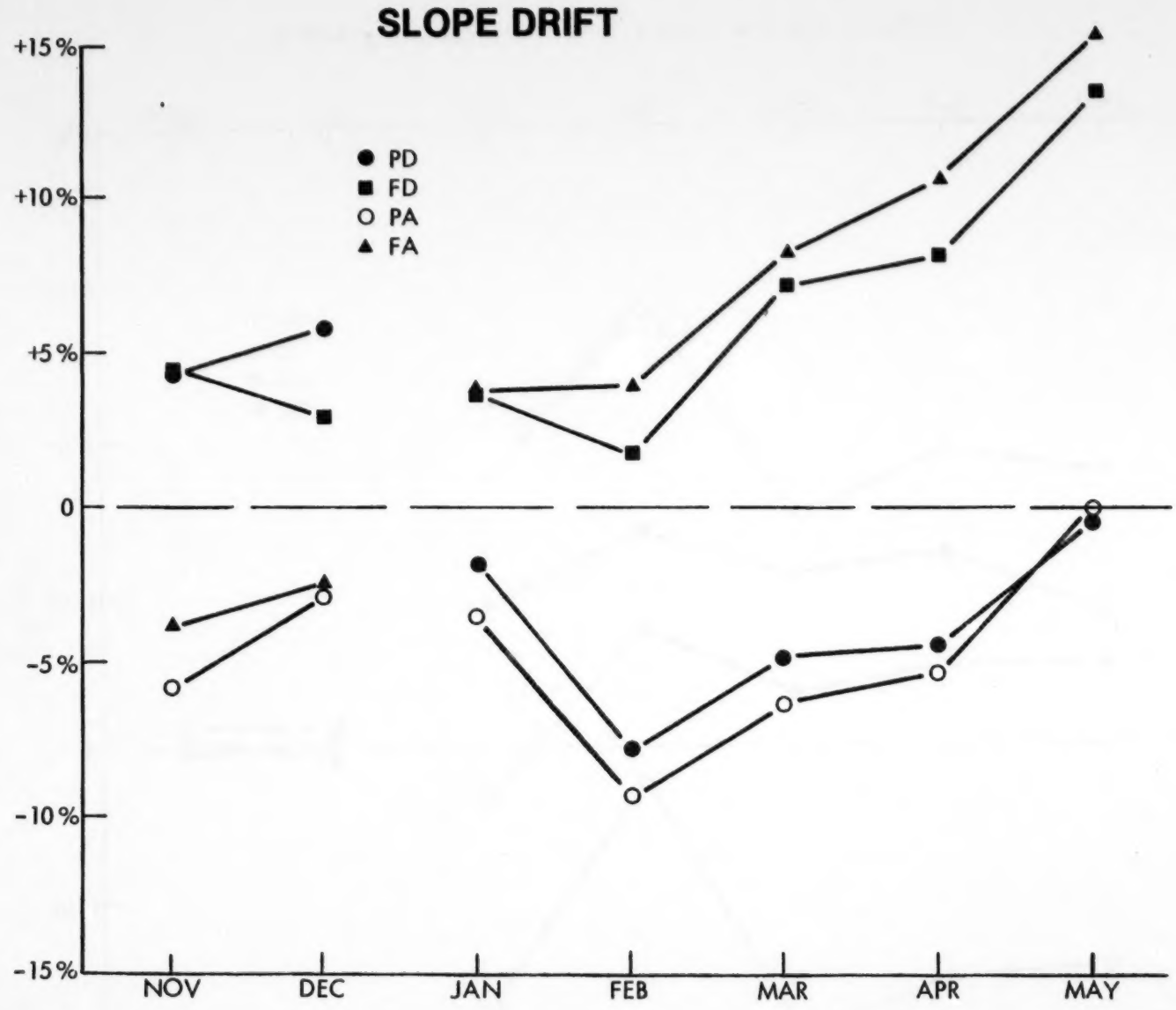

Figure 5. Calibration slope drift - monthly averages.

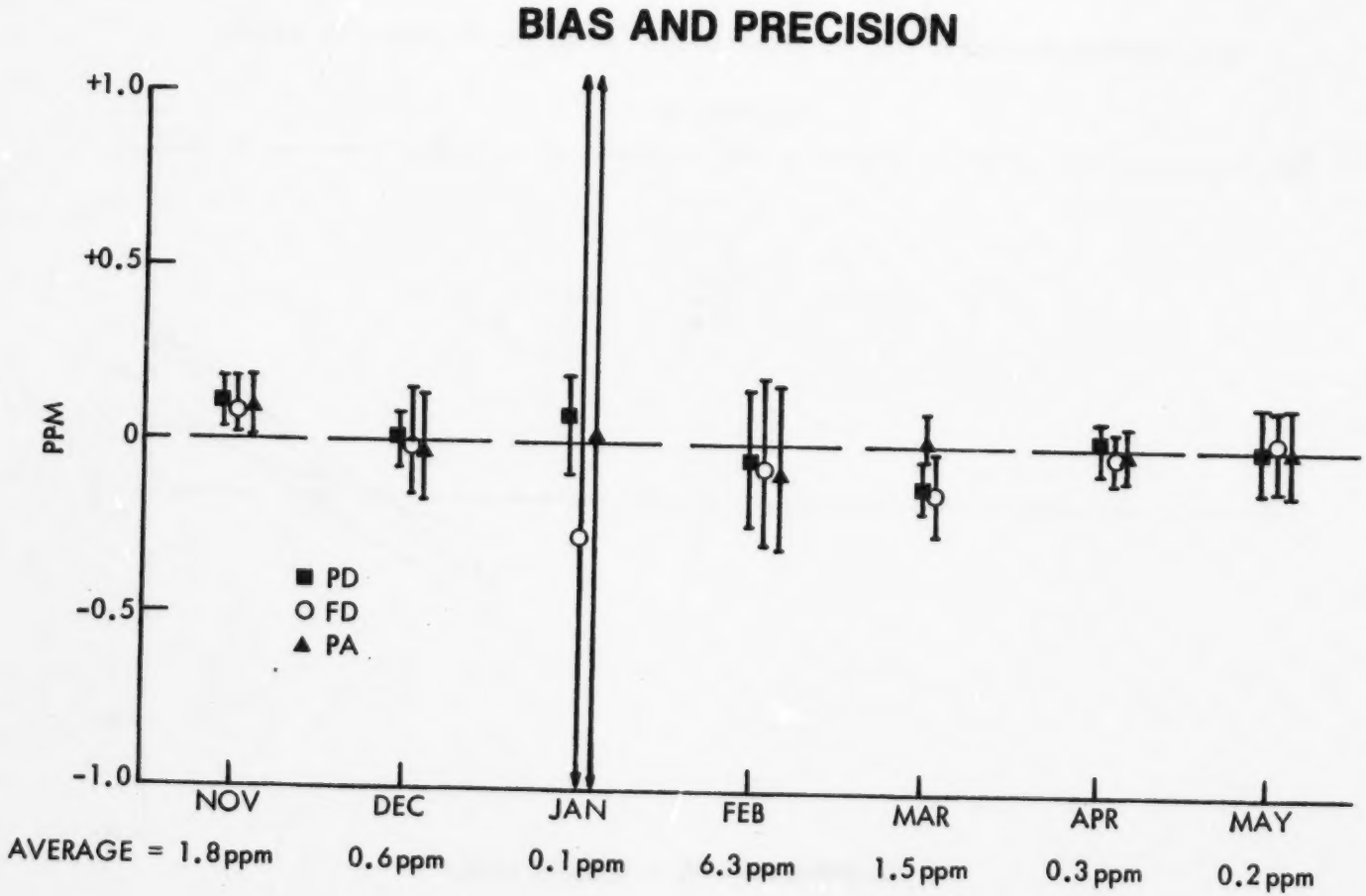

Figure 6. Analyzer bias, compared to FA channel, and precision.

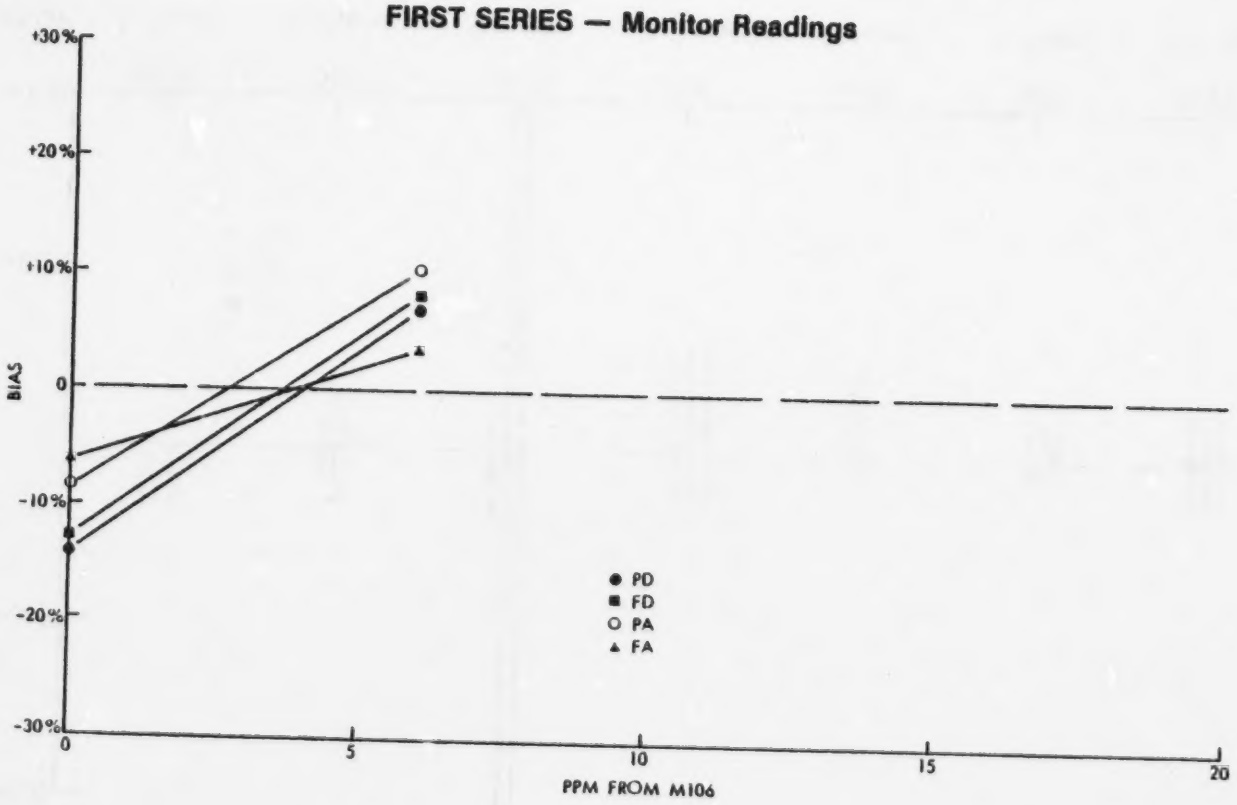

Figure 7. Bias of analyzer direct readings for first equivalence test.

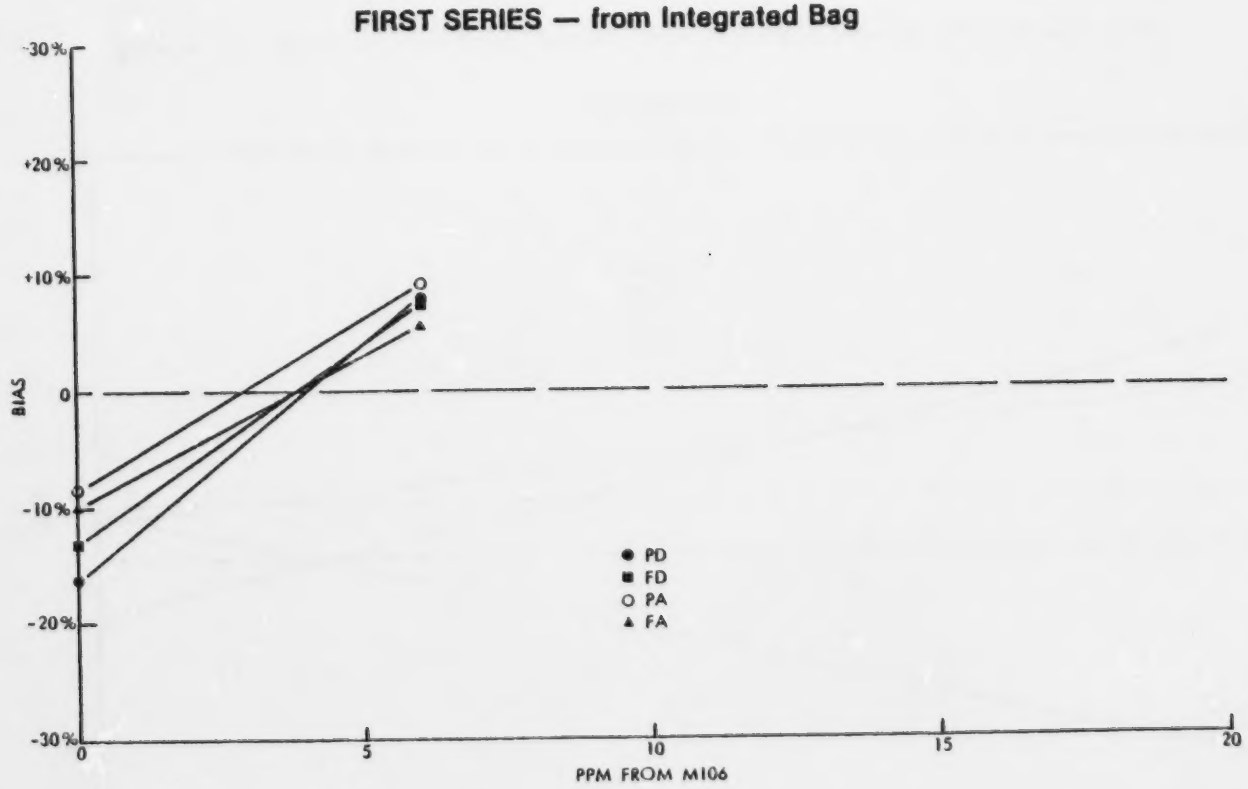

Figure 8. Analyzer bias when sampling from integrated bags for first equivalence test.

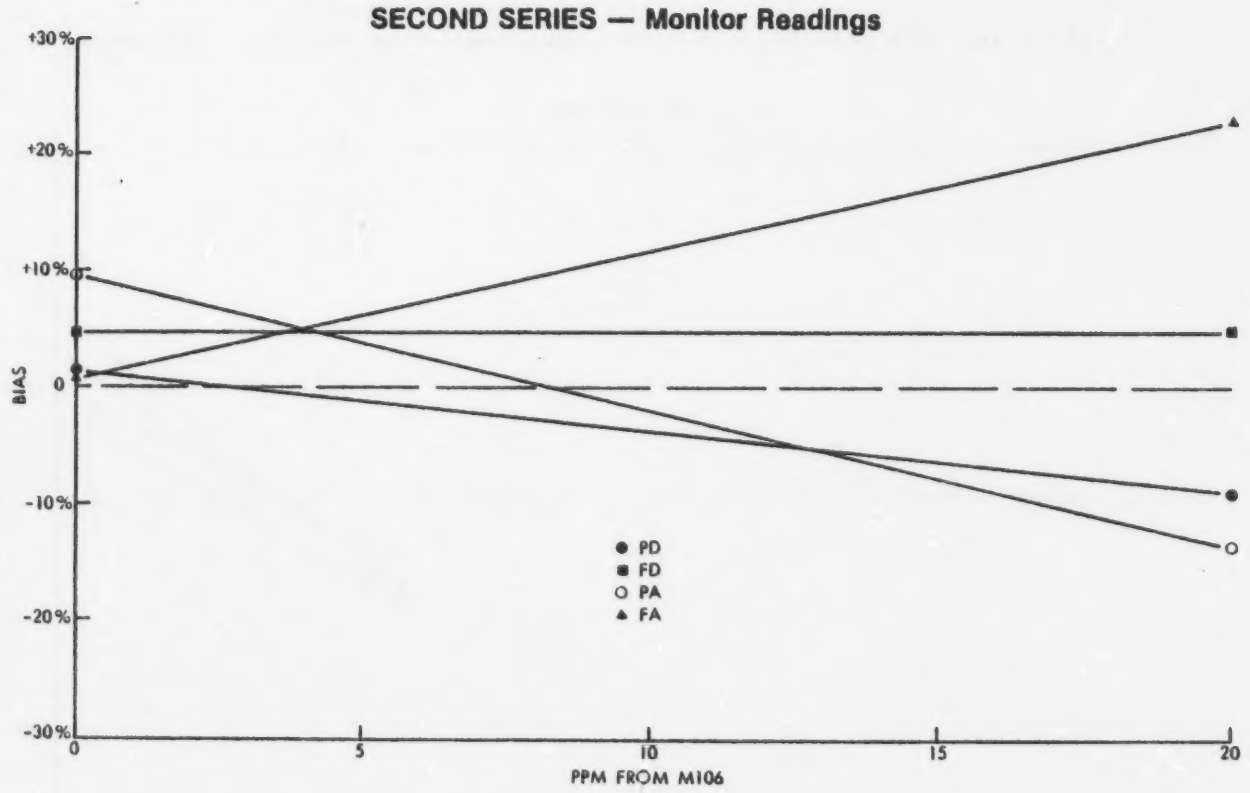

Figure 9. Bias of analyzer direct readings for second equivalence test.

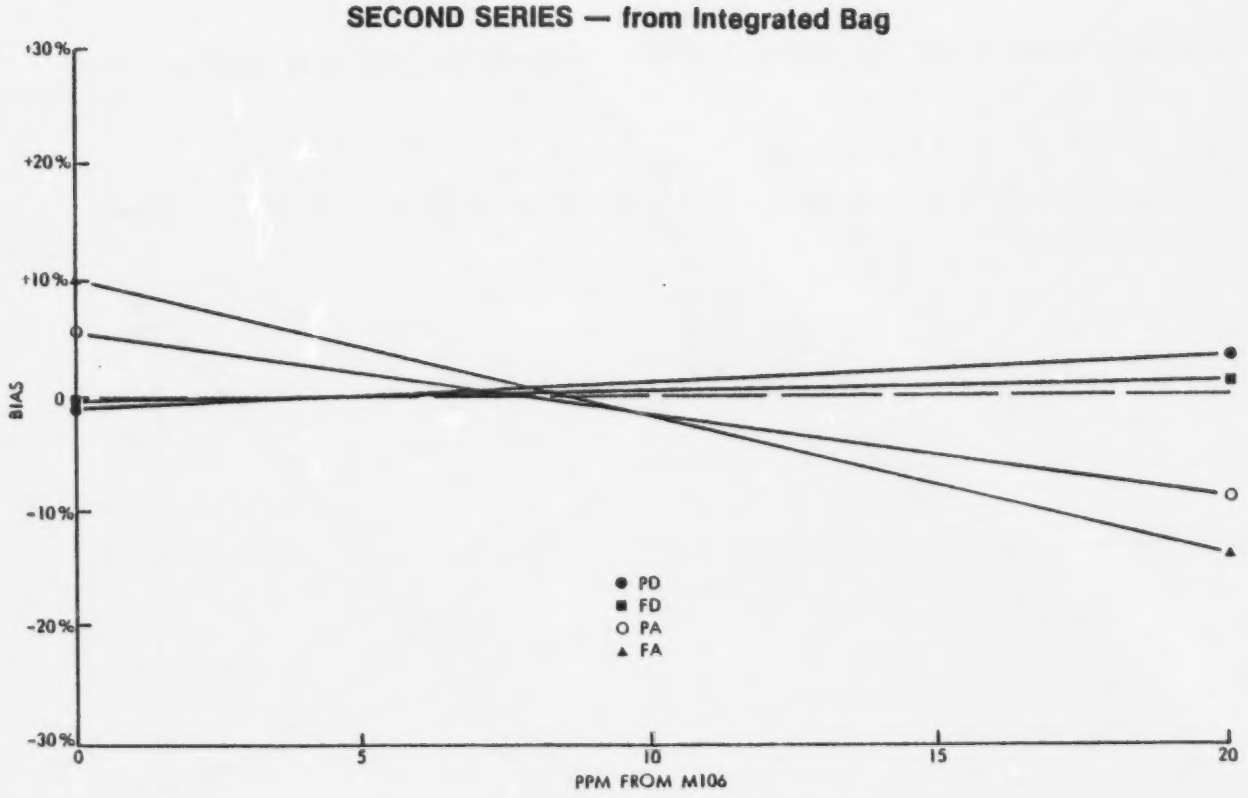

Figure 10. Analyzer bias when sampling from integrated bags for second equivalence test.

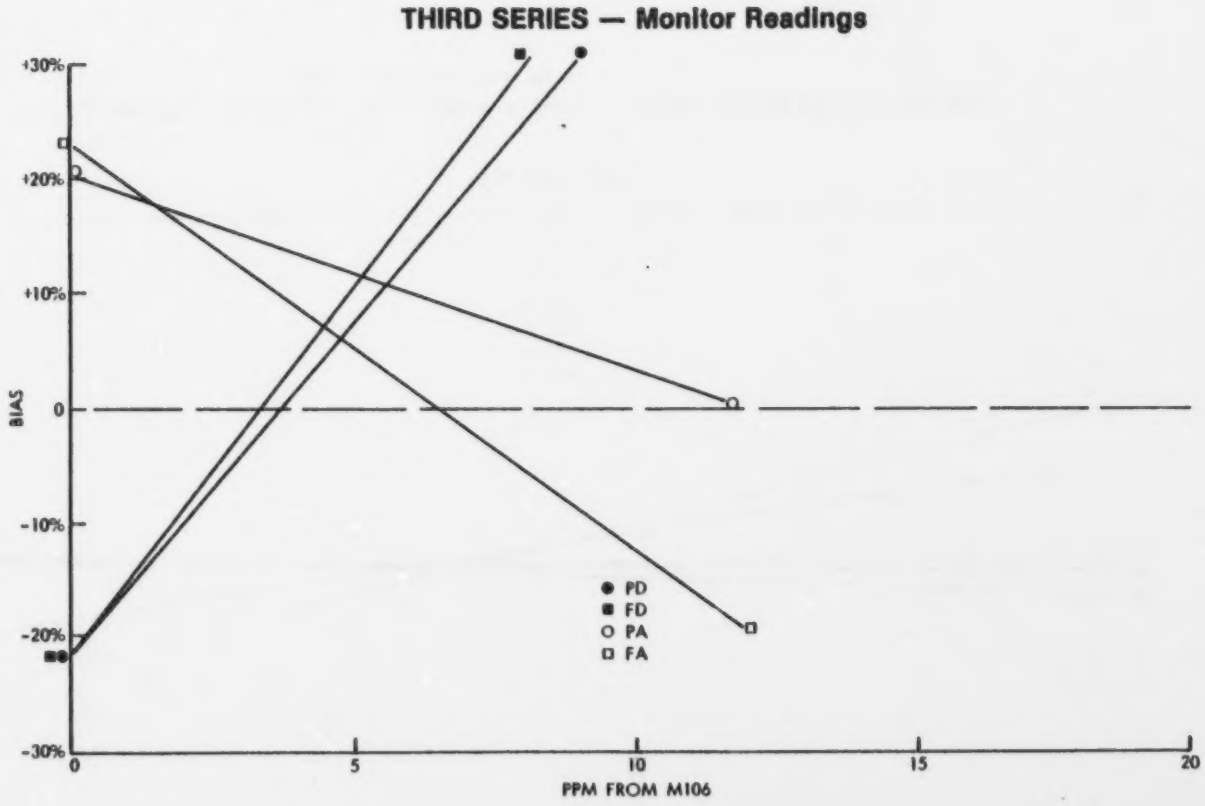

Figure 11. Bias of analyzer direct readings for third equivalence test.

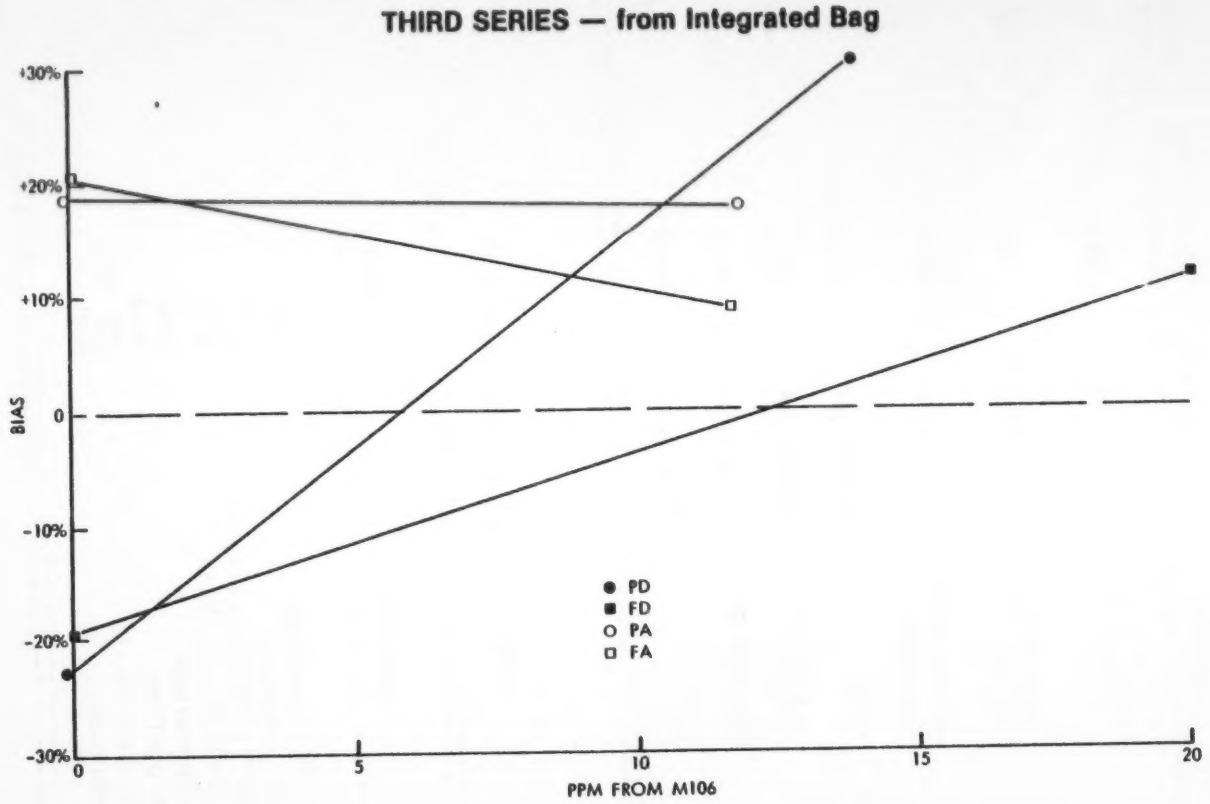

Figure 12. Analyzer bias when sampling from integrated bags for third equivalence test.

TAPLE 1. COMMERCIALLY AVAILABLE TECHNIQUES FOR ANALYSIS OF VINYL CHLORIDE

Typical analyzer	Analysis method	Sensitivity	Selectivity	Cost ($)
Applied Automation 102	Process GC	0-10 ppm	Good	15,000
AID 580	Photoionization	0-2,000 ppm	Poor	4,000
Devco Eng.	Electroconductivity	0-10 ppm	Moderate	4,000
Horiba PIR-2000	NDIR	0-100 ppm	Moderate	3,500
Miran 103 or 1A	Infrared	0-100 ppm	Fair	6-8,000
Bendix 7000	Process GC	0-10 ppm	Good	16-20,000
Carle SX-AGC	GC	0-10 ppm	Good	6,500

TABLE 2. TEST FOR INTERFERENCES

Compound	Effect
Dichloromethane	None
Acetaldehyde	None
cis-1,2-Dichloroethane	None
1,1-Dichloroethane	None
Chloroethane	None
Chloroform	None
Chloromethane	FID only
Isobutane	Both

TABLE 3. LABORATORY TEST OF INDEPENDENT VARIABLES

Variables	Optimum	Test levels	Effect
Analog integration only:			
G1 opens integration window	57 sec	±2 sec	Weak
G1 closes integration window	75 sec	±3 sec	Moderate (0.7%) PA
Digital integration only:			
Noise factor sets slope limit for baseline	4 counts	-1/+2 counts	None
TRIG sets minimum width for baseline	9 readings	±3 readings	Weak
LS starts peak leading edge scan	Max. -20 readings	±10 readings	None[a]
TS starts peak trailing edge scan	Max. +20 readings	±10 readings	None
Flame detector only:			
FID AIR sets pressure for FID air flow orifice	28 psig	±2 psig	None
FID FUEL sets pressure for FID hydrogen flow orifice	9 psig	±1 psig	Strong (8%)
General variables:			
BF starts backflush from stripping column	45 sec	±3 sec	Strong (1.5-5%)
AIR is main instrument supply pressure	80 psig	±20 psig	Strong (4%) at 60 only
VALVE is the valve air supply pressure	50 psig	±5 psig	Moderate (2%) at 45 only
OVEN is the oven air supply pressure	10 psig	±1 psig	None
CARRIER sets the HE carrier control pressure	28 psig	±2 psig	Strong (3-5%)[b]

[a] Standard deviation increased at peak max. -10 setting.

[b] With carrier supply at 30 psig HA was -55% due to peak retention time change to edge of integration window.

TABLE 4. FIELD TEST CHRONOLOGY

Date	Event
November 15, 1983	Analyzer setup completed at field site.
November 16, 1983	Start of test period with afternoon calibration.
November 18, 1983	Start of first equivalence test series.
November 23, 1983	End of first test series.
November 29, 1983	Plant upset dumps liquid organics into analyzer sample line. FID flames out.
December 1, 1983	Flame relit, sample line cleaned.
December 15, 1983	Plant compressed air supply fails. Flame out.
December 19, 1983	Flame relit.
December 24, 1983	Plant compressed air supply fails. Flame out.
December 29, 1983	Flame relit. FID air changed to cylinder air.
January 4, 1984	Analyzer offline for column changes.
January 6, 1984	GC separation column replaced, high contamination levels exceed baseline correction limits.
January 16, 1984	Baseline has stabilized. System timing and integrators reprogrammed. Analyzer online.
January 23, 1984	PD channel baseline drifts negative. Other channels OK.
February 1, 1984	PD channel baseline corrected.
February 4, 1984	Drastic shift in nitrogen dilution. Analyzer overload.
February 19, 1984	Drastic shift in nitrogen dilution. Analyzer overlod.
February 22, 1984	Drastic shift in nitrogen dilution. Analyzer overload.
February 27, 1984	Start of second equivalence test series.
March 2, 1984	End of second test series.
April 3, 1984	Data logger stopped. Power supply failure.
April 10, 1984	Power supply replaced.
April 18, 1984	Data logger stopped. High noise levels create unusual combination of events for a program bug to appear.
April 19, 1984	Program error corrected. High ambient temperatures continue to cause noise problems in the data logger.
May 14, 1984	Start of third equivalence test series.
May 18, 1984	End of third test series. End of performance test.

APPENDIX A

MONTHLY DATA SUMMARIES

Table A-1. Data Recovery for October.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
21	99	1	0	98
22	98	2	0	97
23	99	2	0	97
24	100	2	0	98
25	98	1	0	97
26	100	1	0	99
27	99	2	0	97
28	99	2	0	97
29	100	3	0	97
30	98	1	0	97
31	95	1	0	94
Average:	99	1	0	97

Table A-2. Zero Drift for October.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
21	0.000	0.000	0.000	0.000
22	-0.004	-0.001	-0.035	0.064
23	0.004	-0.004	-0.040	0.000
24	-0.001	-0.005	-0.044	0.004
25	-0.003	0.000	-0.044	0.003
26	0.003	-0.005	-0.014	0.028
27	-0.003	-0.010	-0.018	0.019
28	-0.009	0.003	-0.090	0.061
29	-0.004	0.001	-0.018	0.034
30	0.005	-0.002	-0.012	-0.105
31	-0.001	-0.004	-0.024	0.066
Average:	-0.001	-0.002	-0.031	0.016
Initial Zero Used to Calculate Drift:				
10-21	0.000	0.005	-0.087	-0.126

Table A-3. Span Drift for October.

Date	PD (%)	FD (%)	PA (%)	FA (%)
21	0.00	0.00	0.00	0.00
22	0.08	-0.13	1.90	-2.71
23	1.40	0.92	3.32	-2.02
24	1.24	3.87	5.90	-1.55
25	0.07	-0.85	1.69	-1.34
26	-8.19	3.16	-6.28	1.93
27	-9.68	5.51	-8.04	3.57
28	-8.81	5.64	-4.32	4.11
29	-9.69	1.91	-8.27	6.41
30	-10.16	2.66	-8.24	7.28
31	-8.57	3.52	-7.26	1.26
Average:	-4.76	2.38	-2.69	1.54
Initial Span Used to Calculate Drift:				
10-21	1.206	1.041	1.267	1.099

Table A-4. Bias and Precision for October.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
21	1.74	-0.07	-0.11	-0.01	0.06	0.12
22	1.68	-0.09	-0.12	-0.03	0.05	0.14
23	1.55	-0.02	-0.06	0.02	0.04	0.14
24	1.58	0.00	0.01	0.10	0.05	0.15
25	1.16	0.07	0.00	0.12	0.08	0.10
26	1.20	0.02	-0.04	0.08	0.04	0.11
27	1.48	0.00	0.01	0.07	0.06	0.11
28	1.93	-0.09	-0.08	-0.04	0.05	0.13
29	2.25	-0.09	-0.10	-0.06	0.67	0.39
30	1.87	0.02	-0.04	0.08	0.06	0.10
31	1.95	0.01	-0.04	0.05	0.05	0.08
Average:	1.67	-0.02	-0.05	0.03	0.22	0.17

Table A-5. Data Recovery for November.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
17	77	1	0	76
18	139	1	13	125
19	100	1	10	89
20	93	0	77	16
21	101	1	23	76
22	102	1	38	63
23	100	1	44	55
24	100	0	0	100
25	100	2	0	97
26	100	1	0	99
27	100	2	0	98
28	99	2	0	97
29	75	2	4	69
30	0	0	0	0
Average:	92	1	15	76

Table A-6. Zero Drift for November.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
17	-0.051	-0.072	0.123	-0.044
18	0.052	-0.016	0.205	0.045
19	0.027	-0.023	0.172	-0.005
20	-0.079	-0.062	0.163	-0.079
21	-0.072	-0.010	0.160	-0.050
22	-0.033	-0.024	0.153	-0.078
23	0.005	-0.079	0.160	-0.011
24	0.100	-0.022	0.188	0.059
25	0.008	0.016	0.214	0.020
26	-0.003	0.011	0.214	0.011
27	0.018	0.016	0.202	0.016
28	0.026	-0.020	0.204	0.068
29	0.025	-0.010	0.214	0.022
30	*	*	*	*
Average:	0.002	-0.023	0.182	-0.002
Initial Zero Used to Calculate Drift:				
11-16	0.046	0.069	-0.154	-0.036

* - no data available

Table A-7. Span Drift for November.

Date	PD (%)	FD (%)	PA (%)	FA (%)
17	5.36	11.42	-5.70	-0.04
18	-0.30	4.80	-9.47	-5.41
19	1.55	1.95	-8.57	-6.12
20	7.29	3.72	-6.81	-2.60
21	6.03	3.00	-6.74	-4.75
22	5.48	6.35	-4.13	-2.37
23	5.65	5.94	-5.53	-4.16
24	2.36	3.59	-6.34	-6.61
25	3.01	2.43	-6.82	-5.90
26	5.02	3.05	-6.33	-5.10
27	6.68	4.45	-5.35	-4.02
28	6.39	4.73	-4.47	-5.48
29	5.90	4.61	-4.86	-4.46
30	*	*	*	*
Average:	4.65	4.62	-6.24	-4.39
Initial Span Used to Calculate Drift: 11-16	0.950	0.930	1.037	0.982

* - no data available

Table A-8. Bias and Precision for November.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
17	-0.01	0.01	0.01	0.06	0.04	0.04
18	2.79	-0.17	-0.15	-0.21	0.18	0.11
19	0.72	-0.06	-0.10	-0.03	0.06	0.06
20	10.10	1.13	0.71	0.65	0.07	0.17
21	3.17	0.06	0.08	0.10	0.10	0.13
22	4.43	0.10	0.29	0.34	0.12	0.19
23	2.02	0.03	0.02	0.07	0.13	0.12
24	0.13	0.05	-0.04	-0.06	0.03	0.04
25	0.06	0.00	0.04	0.01	0.02	0.04
26	0.07	0.00	0.05	0.02	0.02	0.04
27	0.11	0.00	0.06	0.03	0.03	0.03
28	0.11	-0.03	-0.04	-0.04	0.02	0.04
29	0.05	0.02	0.02	0.02	0.03	0.04
30	*	*	*	*	*	*
Average:	1.83	0.09	0.07	0.07	0.09	0.06

* - no data available

Table A-9. Data Recovery for December.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
1	55	0	37	18
2	92	1	31	61
3	82	1	32	49
4	93	1	26	66
5	66	1	35	30
6	83	1	8	73
7	98	2	14	82
8	76	1	26	49
9	99	1	1	97
10	100	1	0	99
11	99	0	0	98
12	98	3	1	94
13	91	2	18	71
14	99	2	0	98
15	98	2	0	96
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	98	1	0	97
21	99	1	0	98
22	99	1	0	98
23	100	2	0	98
24	98	1	0	98
25	0	0	0	0
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0
30	99	2	0	97
31	100	2	0	98
1-1	96	2	0	93
1-2	100	2	0	98
1-3	98	3	0	96
1-4	81	2	0	79
Average:	68	1	7	61

Table A-10. Zero Drift for December.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
1	0.025	-0.010	0.215	0.022
2	-0.404	-0.424	-0.153	-0.427
3	-0.205	-0.221	0.008	-0.250
4	-0.112	-0.091	0.111	-0.108
5	-0.041	-0.070	0.125	-0.072
6	0.050	-0.040	0.138	-0.013
7	0.023	0.017	0.227	0.040
8	-0.007	0.009	0.202	0.032
9	0.003	0.001	0.190	0.012
10	0.015	0.017	0.208	0.029
11	0.042	0.027	0.197	0.022
12	0.011	-0.055	0.169	0.016
13	0.039	-0.036	0.174	0.056
14	0.045	-0.013	0.237	0.050
15	0.036	0.023	0.227	0.066
16	*	*	*	*
17	*	*	*	*
18	*	*	*	*
19	*	*	*	*
20	0.067	0.046	0.235	0.077
21	0.067	0.024	0.229	0.094
22	0.016	0.006	0.213	0.035
23	0.046	0.028	0.233	0.058
24	0.055	0.033	0.216	0.075
25	*	*	*	*
26	*	*	*	*
27	*	*	*	*
28	*	*	*	*
29	*	*	*	*
30	0.016	0.100	0.205	0.042
31	-0.004	-0.016	0.200	0.049
1-1	0.003	-0.050	0.175	0.052
1-2	0.015	-0.032	0.188	0.046
1-3	0.018	0.000	0.181	0.068
1-4	-0.029	-0.053	0.192	-0.009
Average:	-0.008	-0.030	0.175	0.002
Initial Zero Used to Calculate Drift:				
11-16	0.046	0.069	-0.154	-0.036

* - no data available

Table A-11. Span Drift for December.

Date	PD (%)	FD (%)	PA (%)	FA (%)
1	5.88	4.63	-4.86	-4.48
2	-3.37	-10.18	-17.72	-17.71
3	-1.81	-7.15	-14.15	-13.94
4	3.75	-2.79	-7.87	-10.93
5	4.88	-0.36	-6.64	-8.30
6	7.02	1.46	-5.08	-6.68
7	7.09	2.63	-3.24	-6.52
8	7.35	2.49	-3.71	-6.91
9	8.94	3.04	-2.50	-4.90
10	8.76	4.29	-2.79	-4.38
11	9.57	4.98	-1.53	-3.84
12	10.61	5.92	-1.31	-3.82
13	10.50	4.81	0.20	-5.12
14	14.06	5.51	1.60	-4.62
15	13.81	4.30	-0.23	-4.70
16	*	*	*	*
17	*	*	*	*
18	*	*	*	*
19	*	*	*	*
20	12.85	3.00	1.45	-4.37
21	12.87	3.60	2.18	-4.91
22	15.18	6.16	2.41	-2.73
23	13.96	4.01	1.89	-3.99
24	13.83	4.76	2.67	-4.00
25	*	*	*	*
26	*	*	*	*
27	*	*	*	*
28	*	*	*	*
29	*	*	*	*
30	-6.52	4.75	-3.19	10.07
31	-5.65	6.82	-3.72	10.62
1-1	-6.29	4.30	-3.96	9.57
1-2	-6.68	4.84	-3.79	9.66
1-3	-5.13	6.30	-1.64	11.16
1-4	-4.54	11.25	-1.51	11.84
Average:	5.42	3.21	-2.96	-2.46

Initial Span Used to Calculate Drift:

11-16	0.950	0.930	1.037	0.982

* - no data available

Table A-12. Bias and Precision for December.

Date	Reference FA (ppm)	---- PD (ppm)	Bias FD (ppm)	---- PA (ppm)	--Precision-Std. Dev.-- Ch1 FD-PA (ppm)	Ch2 PD-FA (ppm)
1	2.68	-0.10	-0.06	-0.06	0.13	0.09
2	1.40	0.07	0.03	0.07	0.13	0.13
3	2.45	-0.02	-0.05	-0.02	0.11	0.10
4	1.35	-0.01	0.02	0.05	0.08	0.05
5	1.49	-0.02	-0.13	-0.09	0.06	0.09
6	0.74	0.09	0.09	0.06	0.09	0.13
7	0.26	0.03	0.06	0.07	0.06	0.12
8	0.18	-0.02	0.03	0.01	0.07	0.09
9	0.12	0.00	0.03	0.00	0.05	0.04
10	0.11	-0.01	0.03	-0.01	0.05	0.04
11	0.12	0.03	0.04	0.00	0.06	0.04
12	0.07	0.01	-0.02	-0.01	0.03	0.05
13	0.24	0.01	-0.05	-0.06	0.04	0.08
14	0.09	0.01	-0.02	0.02	0.04	0.04
15	0.10	-0.01	0.00	-0.01	0.03	0.04
16	*	*	*	*	*	*
17	*	*	*	*	*	*
18	*	*	*	*	*	*
19	*	*	*	*	*	*
20	0.54	-0.02	-0.01	-0.03	0.07	0.04
21	0.74	-0.02	-0.05	-0.04	0.08	0.07
22	0.18	-0.01	0.00	-0.01	0.06	0.04
23	0.39	-0.01	0.01	-0.01	0.08	0.04
24	0.27	-0.01	0.03	-0.01	0.09	0.04
25	*	*	*	*	*	*
26	*	*	*	*	*	*
27	*	*	*	*	*	*
28	*	*	*	*	*	*
29	*	*	*	*	*	*
30	0.11	0.00	0.09	-0.02	0.22	0.02
31	0.54	-0.03	-0.01	-0.06	0.12	0.03
1-1	0.21	-0.02	-0.10	-0.08	0.21	0.03
1-2	0.18	-0.02	-0.03	-0.08	0.17	0.03
1-3	0.24	-0.04	-0.04	-0.12	0.27	0.03
1-4	0.13	-0.01	-0.01	0.01	0.55	0.10
Average:	0.57	0.00	-0.01	-0.02	0.16	0.07

* - no data available

Table A-13. Data Recovery for January.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	95	1	0	94
18	98	1	0	97
19	96	3	0	93
20	97	4	0	93
21	95	1	0	94
22	99	2	0	97
23	98	1	0	97
24	99	0	0	99
25	99	2	0	96
26	99	2	0	97
27	99	1	0	98
28	97	1	0	96
29	100	1	0	99
30	99	1	0	98
31	94	1	9	84
Average:	54	1	0	53

Table A-14. Zero Drift for January.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
5	*	*	*	*
6	*	*	*	*
7	*	*	*	*
8	*	*	*	*
9	*	*	*	*
10	*	*	*	*
11	*	*	*	*
12	*	*	*	*
13	*	*	*	*
14	*	*	*	*
15	*	*	*	*
16	*	*	*	*
17	0.000	0.000	0.000	0.000
18	0.002	0.056	0.288	-0.525
19	0.078	-0.455	0.551	-0.006
20	0.225	0.224	0.147	-0.147
21	0.043	-0.099	-0.060	0.019
22	-0.009	-0.298	0.372	0.006
23	-0.119	-0.089	0.227	-0.109
24	*	-0.223	0.100	-0.480
25	*	-0.139	0.133	-0.337
26	*	-0.131	0.380	-0.046
27	*	-0.202	0.340	-0.120
28	*	-0.124	0.142	-0.218
29	*	-0.196	-0.157	-0.307
30	*	0.253	0.052	-0.169
31	*	0.049	-0.060	-0.169
Average:	0.032	-0.092	0.164	-0.174

Initial Zero Used to Calculate Drift:

01-17	0.097	0.143	-0.386	0.036

* - no data available

Table A-15. Span Drift for January.

Date	PD (%)	FD (%)	PA (%)	FA (%)
5	*	*	*	*
6	*	*	*	*
7	*	*	*	*
8	*	*	*	*
9	*	*	*	*
10	*	*	*	*
11	*	*	*	*
12	*	*	*	*
13	*	*	*	*
14	*	*	*	*
15	*	*	*	*
16	*	*	*	*
17	0.00	0.00	0.00	0.00
18	2.69	-1.73	-3.21	-4.25
19	1.91	7.27	-3.19	-1.01
20	-3.48	-2.69	2.95	-6.57
21	-6.89	-2.71	-1.97	-0.85
22	-4.52	-4.81	-5.01	-0.72
23	-2.46	-1.22	-1.81	-3.94
24	*	-2.63	-3.91	0.80
25	*	-3.06	-6.70	1.39
26	*	0.02	-6.18	-0.12
27	*	0.59	-9.02	1.19
28	*	14.28	-2.32	16.43
29	*	22.60	-1.93	20.62
30	*	12.66	-6.26	16.33
31	*	17.77	-5.07	17.30
Average:	-1.82	3.76	-3.58	3.77
Initial Span Used to Calculate Drift:				
01-17	1.000	1.127	1.054	1.170

* - no data available

Table A-16. Bias and Precision for January.

Date	Reference FA (ppm)	---- PD (ppm)	Bias FD (ppm)	---- PA (ppm)	--Precision-Std. Dev.-- Ch1 FD-PA (ppm)	Ch2 PD-FA (ppm)
5	*	*	*	*	*	*
6	*	*	*	*	*	*
7	*	*	*	*	*	*
8	*	*	*	*	*	*
9	*	*	*	*	*	*
10	*	*	*	*	*	*
11	*	*	*	*	*	*
12	*	*	*	*	*	*
13	*	*	*	*	*	*
14	*	*	*	*	*	*
15	*	*	*	*	*	*
16	*	*	*	*	*	*
17	0.60	-0.06	-0.06	-0.25	0.55	0.24
18	-0.30	0.41	0.50	0.48	0.43	0.24
19	0.19	-0.02	-2.07	0.16	4.66	0.23
20	-0.03	0.39	-1.41	0.08	4.56	0.17
21	0.07	0.07	-1.61	-0.33	10.20	0.13
22	0.14	-0.04	-0.75	-0.01	1.62	0.19
23	0.12	-0.15	-0.05	-0.09	0.20	0.19
24	-0.05	*	-0.06	0.00	0.22	*
25	-0.24	*	0.25	0.27	0.43	*
26	0.01	*	0.05	0.25	0.30	*
27	0.03	*	-0.05	0.21	0.30	*
28	-0.05	*	0.10	0.09	0.39	*
29	-0.15	*	0.13	-0.10	0.36	*
30	0.00	*	0.41	-0.03	0.36	*
31	1.28	*	0.09	-0.22	0.75	*
Average:	0.11	0.09	-0.30	0.03	3.29	0.22

* - no data available

Table A-17. Data Recovery for February.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
1	97	2	1	94
2	95	0	6	89
3	88	1	28	58
4	69	0	69	0
5	51	0	51	0
6	84	0	11	72
7	78	0	24	54
8	83	0	19	63
9	74	0	26	47
10	58	0	54	4
11	88	0	88	0
12	53	0	37	15
13	76	0	20	56
14	80	0	16	63
15	85	1	27	57
16	91	0	91	0
17	70	0	43	27
18	102	0	102	0
19	87	0	87	0
20	66	0	66	0
21	65	0	44	21
22	58	0	58	0
23	52	0	48	4
24	53	0	36	16
25	59	0	38	22
26	72	0	46	26
27	75	0	44	31
28	96	1	1	93
29	95	0	5	90
Average:	76	0	41	35

Table A-18. Zero Drift for February.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
1	*	0.106	0.264	-0.096
2	0.024	-0.097	0.038	-0.061
3	0.088	-0.106	0.048	-0.313
4	*	*	*	*
5	-0.327	-0.478	-0.162	-0.710
6	-0.089	-0.206	0.136	-0.189
7	0.051	-0.078	0.298	-0.036
8	0.004	-0.083	0.387	-0.021
9	0.013	-0.147	0.047	-0.060
10	-0.063	-0.142	0.034	-0.268
11	-0.115	-0.190	0.051	-0.233
12	-0.356	-0.426	-0.502	-0.740
13	-0.067	-0.158	-0.117	-0.370
14	-0.084	-0.189	0.093	-0.341
15	-0.058	-0.113	0.117	-0.197
16	-0.114	-0.131	0.135	-0.252
17	-0.114	-0.160	-0.204	-0.279
18	-0.486	-0.583	-0.711	-1.006
19	*	*	*	*
20	-0.187	-0.124	-0.071	-0.411
21	-0.139	-0.115	0.226	-0.229
22	*	*	*	*
23	-0.201	-0.258	0.146	-0.242
24	-0.071	-0.178	-0.087	-0.244
25	-0.015	-0.066	0.149	-0.204
26	-0.021	-0.151	0.146	-0.187
27	-0.132	0.134	0.042	-0.394
28	0.039	-0.136	0.230	-0.180
29	-0.044	-0.065	0.096	-0.107
Average:	-0.098	-0.159	0.032	-0.283

Initial Zero Used to Calculate Drift:

01-17	0.097	0.143	-0.386	0.036

* - no data available

Table A-19. Span Drift for February.

Date	PD (%)	FD (%)	PA (%)	FA (%)
1	*	15.77	-7.93	17.06
2	-6.25	17.04	-5.98	16.82
3	-4.27	15.15	-7.42	15.58
4	*	*	*	*
5	-7.61	0.05	-13.61	1.56
6	-3.87	4.37	-8.79	3.79
7	-0.51	3.66	-5.17	0.55
8	-6.90	3.62	-9.39	0.74
9	-6.56	3.14	-13.31	1.29
10	-4.96	2.03	-6.64	3.75
11	-8.43	4.83	-9.89	2.55
12	-12.71	-4.29	-16.14	-0.61
13	-8.91	2.39	-8.99	3.65
14	-9.57	3.23	-7.69	2.59
15	-7.93	-4.32	-12.44	0.02
16	-6.53	-2.31	-12.29	0.49
17	-10.25	0.74	-9.98	0.64
18	-18.16	-12.22	-17.60	2.13
19	*	*	*	*
20	-11.93	-7.42	-14.41	0.41
21	-10.07	0.47	-10.51	1.42
22	*	*	*	*
23	-13.50	-0.60	-12.40	-1.87
24	-8.34	2.98	-6.26	4.88
25	-7.33	2.24	-7.16	5.37
26	-9.77	4.65	-6.54	5.08
27	-10.10	-11.01	-15.34	4.15
28	-7.47	4.61	-7.23	5.59
29	-7.16	2.97	-8.74	4.27
Average:	-8.36	1.99	-10.07	3.92
Initial Span Used to Calculate Drift:				
	-16.000	1.000	1.127	1.054	1.170

* - no data available

Table A-20. Bias and Precision for February.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
1	0.61	-0.37	0.14	0.06	0.42	0.44
2	1.14	-0.10	-0.12	-0.19	0.38	0.30
3	0.57	0.13	-0.09	-0.03	0.30	0.17
4	*	*	*	*	*	*
5	*	*	*	*	*	*
6	6.66	0.07	-0.02	-0.23	0.32	0.34
7	5.01	0.09	0.04	0.16	0.36	0.34
8	6.70	0.00	0.11	0.02	0.33	0.31
9	7.41	0.17	0.06	-0.53	0.37	0.30
10	10.85	0.47	-0.90	-0.54	0.22	0.26
11	*	*	*	*	*	*
12	10.13	0.03	-0.31	-0.78	0.24	0.23
13	6.64	-0.07	-0.09	-0.22	0.25	0.26
14	5.06	-0.19	-0.05	0.08	0.31	0.34
15	5.39	-0.09	-0.37	-0.18	0.24	0.25
16	*	*	*	*	*	*
17	7.55	-0.06	0.02	-0.33	0.22	0.20
18	*	*	*	*	*	*
19	*	*	*	*	*	*
20	*	*	*	*	*	*
21	10.24	-0.11	0.16	-0.08	0.22	0.21
22	*	*	*	*	*	*
23	10.59	0.00	-0.03	-0.15	0.21	0.18
24	9.96	-0.01	-0.03	-0.12	0.21	0.18
25	9.34	0.02	0.11	0.13	0.32	0.28
26	5.48	-0.22	0.02	0.11	0.24	0.22
27	5.28	-0.27	-0.38	-0.45	0.59	0.46
28	4.35	-0.14	0.00	0.24	0.49	0.34
29	3.81	-0.26	-0.11	-0.10	0.41	0.32
Average:	6.32	-0.04	-0.09	-0.15	0.34	0.30

* - no data available

Table A-21. Data Recovery for March.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
1	88	1	15	73
2	97	1	0	96
3	97	0	0	97
4	99	1	0	98
5	98	1	0	97
6	100	0	0	100
7	98	0	0	98
8	100	0	0	100
9	99	1	0	98
10	100	0	0	99
11	99	0	0	98
12	100	1	0	99
13	99	0	0	98
14	100	1	0	99
15	99	1	0	98
16	100	1	0	98
17	99	1	0	99
18	99	0	0	99
19	99	0	0	99
20	100	0	0	100
21	99	0	0	99
22	100	1	0	99
23	99	0	0	99
24	100	1	0	99
25	99	0	0	99
26	99	0	0	99
27	99	0	0	99
28	99	0	0	99
29	99	1	0	98
30	100	0	0	100
31	98	0	0	98
Average:	99	1	0	98

Table A-22. Zero Drift for March.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
1	-0.010	-0.188	0.100	-0.122
2	-0.032	-0.113	0.159	-0.181
3	-0.028	-0.164	0.144	-0.210
4	-0.069	-0.088	0.070	-0.181
5	-0.021	-0.068	0.280	-0.147
6	-0.058	-0.163	0.135	-0.218
7	-0.007	-0.097	0.425	-0.148
8	-0.038	-0.122	0.296	-0.098
9	-0.121	-0.112	0.144	-0.157
10	-0.034	-0.120	0.222	-0.122
11	0.094	-0.069	0.264	-0.174
12	-0.015	-0.116	0.164	-0.174
13	-0.140	-0.090	0.074	-0.118
14	-0.025	-0.151	0.071	-0.239
15	-0.024	-0.113	0.064	-0.144
16	-0.133	-0.134	0.104	-0.252
17	0.027	-0.077	0.198	-0.216
18	0.077	-0.098	0.110	-0.144
19	-0.052	-0.044	0.206	-0.183
20	0.025	-0.157	0.264	-0.119
21	-0.039	-0.104	0.279	-0.144
22	-0.055	-0.083	0.279	-0.168
23	-0.009	-0.086	0.015	-0.128
24	-0.104	-0.130	0.096	-0.179
25	-0.102	-0.101	0.174	-0.127
26	0.040	-0.096	0.228	-0.118
27	-0.185	-0.155	0.240	-0.132
28	-0.003	-0.135	0.363	-0.104
29	-0.120	-0.067	0.301	-0.046
30	0.043	-0.028	0.272	-0.115
31	0.048	-0.082	0.188	-0.099
Average:	-0.035	-0.108	0.191	-0.152
Initial Zero Used to Calculate Drift:				
01-17	0.097	0.143	-0.386	0.036

Table A-23. Span Drift for March.

Date	PD (%)	FD (%)	PA (%)	FA (%)
1	-6.38	3.21	-7.14	5.56
2	-5.20	6.62	-7.25	7.16
3	-6.21	4.41	-5.05	6.87
4	-4.31	4.95	-6.84	7.21
5	-7.09	6.83	-7.35	7.40
6	-5.77	5.25	-5.37	7.71
7	-5.37	3.73	-7.08	5.66
8	-7.05	4.63	-7.94	5.11
9	-2.80	4.28	-6.48	5.65
10	-6.06	4.53	-7.32	6.13
11	-6.76	6.10	-7.66	6.49
12	-6.81	7.86	-4.31	7.29
13	-5.02	6.18	-1.26	6.74
14	-8.21	7.66	-6.38	8.65
15	-8.39	8.02	-6.29	7.61
16	-6.92	8.41	-6.99	9.55
17	-5.87	8.21	-8.43	10.06
18	-6.30	8.16	-5.73	9.18
19	-3.16	7.62	-5.17	9.76
20	-3.53	8.24	-4.27	9.89
21	-4.36	7.71	-5.28	8.57
22	-5.23	7.61	-6.85	9.66
23	-3.84	8.03	-3.17	8.85
24	-4.08	7.96	-5.15	10.38
25	-2.68	8.71	-5.15	10.21
26	-4.10	8.29	-5.89	9.65
27	-0.13	10.58	-5.92	9.99
28	-1.64	12.39	-6.64	11.85
29	-0.65	9.38	-7.37	8.62
30	-4.61	6.45	-7.22	8.26
31	-4.40	8.68	-6.69	8.05
Average:	-4.93	7.12	-6.12	8.19
Initial Span Used to Calculate Drift:				
01-17	1.000	1.127	1.054	1.170

Table A-24. Bias and Precision for March.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
1	2.84	-0.19	-0.32	-0.20	0.25	0.22
2	4.35	-0.15	-0.01	0.04	0.26	0.25
3	5.65	-0.08	-0.20	0.08	0.23	0.29
4	6.79	0.05	-0.10	-0.23	0.23	0.24
5	3.54	-0.27	-0.19	0.03	0.21	0.21
6	1.30	-0.22	-0.26	-0.05	0.18	0.16
7	0.98	-0.12	-0.16	0.18	0.23	0.19
8	1.62	-0.24	-0.23	0.01	0.22	0.19
9	1.14	-0.27	-0.22	-0.08	0.23	0.16
10	1.71	-0.20	-0.22	-0.02	0.24	0.18
11	3.59	-0.01	-0.09	0.11	0.21	0.23
12	1.30	-0.21	-0.23	-0.02	0.18	0.15
13	1.99	-0.32	-0.28	0.02	0.21	0.17
14	2.22	-0.20	-0.27	0.00	0.16	0.18
15	1.61	-0.27	-0.31	-0.08	0.16	0.15
16	1.50	-0.30	-0.25	0.02	0.19	0.15
17	1.03	-0.11	-0.14	0.04	0.21	0.16
18	0.85	-0.07	-0.17	-0.10	0.23	0.16
19	0.55	-0.09	-0.03	0.08	0.21	0.13
20	0.17	0.08	-0.06	0.01	0.18	0.11
21	0.34	-0.02	-0.03	0.06	0.23	0.14
22	0.37	-0.03	-0.01	0.08	0.21	0.15
23	0.44	-0.04	-0.07	-0.16	0.23	0.14
24	0.42	-0.09	-0.08	-0.02	0.22	0.13
25	0.27	-0.08	-0.04	-0.02	0.22	0.13
26	0.20	0.09	0.00	0.01	0.23	0.13
27	0.34	-0.20	-0.12	0.05	0.23	0.13
28	0.27	-0.03	-0.11	0.14	0.21	0.11
29	0.18	-0.12	-0.02	0.01	0.20	0.11
30	0.14	0.10	0.07	0.03	0.20	0.11
31	0.19	0.07	-0.01	-0.03	0.21	0.12
Average:	1.54	-0.11	-0.13	0.00	0.22	0.17

Table A-25. Data Recovery for April.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
1	100	0	0	100
2	98	0	0	98
3	66	2	0	64
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	30	1	0	29
11	99	1	0	97
12	100	1	0	99
13	99	1	0	98
14	100	1	0	99
15	28	0	0	28
16	45	0	0	45
17	100	1	0	99
18	0	0	0	0
19	35	0	0	34
20	99	0	0	99
21	98	0	18	79
22	99	0	70	28
23	97	1	1	95
24	100	1	0	99
25	97	2	0	95
26	100	1	0	99
27	98	1	0	97
28	99	0	0	99
29	99	1	0	98
30	100	2	0	98
Average:	66	1	3	63

Table A-26. Zero Drift for April.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
1	-0.027	-0.069	0.336	-0.161
2	-0.013	-0.158	0.079	-0.133
3	0.013	-0.114	-0.064	-0.177
4	*	*	*	*
5	*	*	*	*
6	*	*	*	*
7	*	*	*	*
8	*	*	*	*
9	*	*	*	*
10	0.013	-0.114	-0.064	-0.177
11	-0.040	-0.138	0.107	-0.178
12	-0.053	-0.125	0.251	-0.229
13	-0.047	-0.114	0.140	-0.233
14	-0.016	-0.148	0.218	-0.205
15	-0.072	-0.094	0.177	-0.214
0	-0.072	-0.094	0.177	-0.214
17	-0.032	-0.118	0.183	-0.079
18	*	*	*	*
19	-0.060	-0.146	0.257	-0.096
20	-0.135	-0.134	0.139	-0.176
21	-0.050	-0.037	0.133	-0.166
22	-0.190	-0.357	-0.131	-0.427
23	-0.059	-0.054	0.201	-0.281
24	-0.071	-0.092	0.122	-0.135
25	-0.073	-0.109	0.248	-0.170
26	-0.011	-0.143	0.220	-0.194
27	-0.059	-0.130	0.168	-0.149
28	-0.112	-0.103	0.219	-0.291
29	-0.109	-0.119	0.227	-0.155
30	-0.051	-0.151	0.066	-0.188
Average:	-0.058	-0.124	0.148	-0.193

Initial Zero Used to Calculate Drift:

01-17	0.097	0.143	-0.386	0.036

* - no data available

Table A-27. Span Drift for April.

Date	PD (%)	FD (%)	PA (%)	FA (%)
1	-4.74	8.60	-7.85	9.05
2	-3.09	11.21	-7.51	13.48
3	-2.00	8.88	-4.70	10.80
4	*	*	*	*
5	*	*	*	*
6	*	*	*	*
7	*	*	*	*
8	*	*	*	*
9	*	*	*	*
10	-2.00	8.88	-4.70	10.80
11	-4.67	8.47	-5.03	10.00
12	-5.73	9.68	-6.07	9.82
13	-4.28	7.64	-6.13	11.62
14	-4.60	9.07	-6.48	10.82
15	-4.55	7.44	-6.14	11.17
16	-4.55	7.44	-6.14	11.17
17	-5.42	6.09	-4.46	7.18
18	*	*	*	*
19	-4.87	7.39	-6.14	6.79
20	-2.64	9.67	-4.37	12.32
21	-4.50	9.49	-3.62	12.52
22	-13.62	1.47	-10.67	3.78
23	-5.26	7.78	-5.30	11.66
24	-4.37	9.15	-1.18	10.79
25	-2.60	9.17	-3.75	11.00
26	-3.01	10.85	-3.76	12.38
27	-3.77	10.31	-2.44	11.78
28	-3.25	9.42	-4.49	14.20
29	-3.69	9.72	-2.89	12.00
30	-3.03	10.59	-1.87	12.08
Average:	-4.36	8.63	-5.03	10.75
Initial Span Used to Calculate Drift: 01-17	1.000	1.127	1.054	1.170

* - no data available

Table A-28. Bias and Precision for April.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
1	0.13	0.06	0.07	0.17	0.20	0.11
2	0.08	0.10	-0.05	-0.05	0.19	0.13
3	0.35	0.05	-0.13	-0.32	0.34	0.34
4	*	*	*	*	*	*
5	*	*	*	*	*	*
6	*	*	*	*	*	*
7	*	*	*	*	*	*
8	*	*	*	*	*	*
9	*	*	*	*	*	*
10	0.52	0.08	-0.08	-0.28	0.13	0.19
11	0.06	0.05	0.00	-0.05	0.10	0.10
12	0.00	0.09	0.07	0.15	0.11	0.09
13	0.02	0.08	0.06	0.03	0.11	0.10
14	0.01	0.11	0.02	0.07	0.10	0.09
15	-0.07	0.10	0.13	0.04	0.10	0.08
16	-0.04	0.09	0.11	0.06	0.11	0.09
17	0.07	0.01	-0.03	-0.09	0.10	0.08
18	*	*	*	*	*	*
19	0.38	-0.01	-0.10	0.01	0.18	0.18
20	0.02	-0.03	0.00	-0.03	0.13	0.10
21	0.56	-0.04	0.06	0.00	0.18	0.14
22	3.01	-0.17	-0.17	-0.10	0.17	0.23
23	1.57	-0.08	-0.01	0.11	0.18	0.15
24	0.45	-0.14	-0.11	-0.09	0.17	0.14
25	0.20	-0.04	-0.03	0.05	0.13	0.11
26	0.16	0.04	-0.05	0.07	0.10	0.09
27	0.18	-0.05	-0.09	-0.04	0.09	0.14
28	0.00	0.05	0.11	0.17	0.10	0.09
29	0.08	-0.04	-0.01	0.06	0.09	0.09
30	0.03	0.04	-0.01	-0.08	0.07	0.08
Average:	0.34	0.02	-0.01	-0.01	0.15	0.14

* - no data available

Table A-29. Data Recovery for May.

Date	Total (%)	Rejected (%)	Over-range (%)	Net Usable (%)
1	99	1	0	98
2	100	0	0	100
3	99	1	0	97
4	100	1	0	99
5	99	1	0	98
6	100	1	0	99
7	98	1	0	97
8	99	1	0	99
9	99	1	0	98
10	100	1	0	99
11	98	0	0	98
12	100	2	0	98
13	100	0	0	99
14	98	3	3	93
15	89	2	3	84
16	95	0	9	85
17	95	2	12	81
18	71	2	4	65
Average:	97	1	2	94

Table A-30. Zero Drift for May.

Date	PD (ppm)	FD (ppm)	PA (ppm)	FA (ppm)
1	-0.073	-0.145	0.162	-0.158
2	-0.103	-0.099	0.175	-0.228
3	-0.088	0.279	0.158	-0.177
4	-0.032	-0.095	0.129	-0.147
5	-0.081	-0.145	0.085	-0.205
6	-0.041	0.135	0.237	-0.289
7	0.082	-0.148	0.188	-0.180
8	-0.096	-0.100	0.168	-0.168
9	-0.084	-0.088	0.185	-0.157
10	0.028	-0.108	0.204	-0.277
11	-0.061	-0.113	0.279	-0.160
12	-0.103	-0.071	0.155	-0.138
13	-0.017	-0.070	0.111	-0.101
14	-0.044	-0.117	0.219	-0.101
15	-0.305	-0.343	-0.042	-0.513
16	0.016	-0.268	-0.059	-0.194
17	-0.083	-0.124	0.224	-0.093
18	-0.092	-0.090	0.154	-0.049
Average:	-0.065	-0.095	0.152	-0.185
Initial Zero Used to Calculate Drift:				
01-17	0.097	0.143	-0.386	0.036

Table A-31. Span Drift for May.

Date	PD (%)	FD (%)	PA (%)	FA (%)
1	-2.35	9.19	-2.21	10.61
2	-3.07	11.60	-4.08	13.81
3	-1.13	10.26	-0.81	14.21
4	-1.75	13.64	-0.80	15.74
5	-0.24	9.47	-0.37	15.13
6	-0.53	4.13	-1.07	16.22
7	-6.28	13.68	-1.51	15.87
8	-1.11	15.80	-0.73	14.92
9	-0.52	11.00	-1.41	13.09
10	-1.29	12.00	-1.24	15.54
11	-0.32	14.07	-0.71	14.33
12	-0.14	13.06	0.01	13.93
13	0.14	12.39	0.53	13.15
14	-0.31	14.17	-0.25	14.35
15	15.25	32.30	14.35	33.87
16	-0.32	19.35	5.07	18.52
17	-0.31	12.22	-2.22	12.95
18	-1.93	14.97	-2.86	14.83
Average:	-0.34	13.52	-0.02	15.61
Initial Span Used to Calculate Drift:				
01-17	1.000	1.127	1.054	1.170

Table A-32. Bias and Precision for May.

Date	Reference FA (ppm)	Bias PD (ppm)	Bias FD (ppm)	Bias PA (ppm)	Precision-Std. Dev. Ch1 FD-PA (ppm)	Precision-Std. Dev. Ch2 PD-FA (ppm)
1	0.05	0.00	-0.03	-0.01	0.08	0.09
2	-0.03	0.04	0.09	0.06	0.07	0.08
3	0.02	0.01	0.42	0.01	0.09	0.09
4	0.06	0.02	0.03	-0.06	0.09	0.09
5	-0.03	0.06	0.03	-0.05	0.08	0.09
6	-0.09	0.16	0.38	0.18	0.07	0.09
7	0.01	0.18	0.00	0.03	0.07	0.09
8	0.00	0.01	0.05	-0.01	0.09	0.08
9	0.00	0.02	0.06	-0.04	0.09	0.08
10	-0.13	0.26	0.16	0.12	0.09	0.08
11	0.00	0.04	0.04	0.07	0.08	0.09
12	0.02	-0.02	0.05	-0.06	0.08	0.08
13	0.05	0.03	0.02	-0.13	0.08	0.08
14	0.68	-0.07	-0.14	-0.04	0.25	0.26
15	0.25	-0.01	-0.04	0.10	0.30	0.33
16	1.07	0.03	-0.14	-0.18	0.17	0.18
17	0.86	-0.15	-0.12	0.00	0.20	0.25
18	0.78	-0.17	-0.17	-0.14	0.24	0.34
Average:	0.20	0.02	0.04	-0.01	0.15	0.17

APPENDIX B

COMPARATIVE TESTS OF MONITOR AND METHOD 106

Table B-1. Average Readings for each Run - First Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
1	2.72	2.65	2.58	2.70	2.56	2.68	2.66	2.81	2.74	2.71	2.63
2	3.20	2.94	2.93	3.00	3.03	2.97	3.01	3.09	3.08	3.00	3.01
3	2.53	2.50	2.47	2.58	2.58	2.58	2.61	2.71	2.67	2.59	2.58
4	1.59	1.47	1.57	1.52	1.58	1.54	1.60	1.63	1.66	1.54	1.60
5	0.72	0.54	0.52	0.54	0.51	0.59	0.56	0.66	0.55	0.58	0.54
6	0.78	0.73	0.75	0.73	0.77	0.78	0.81	0.81	0.84	0.76	0.79
7	0.60	0.59	0.49	0.53	0.48	0.63	0.54	0.64	0.56	0.60	0.52
8	0.45	0.47	0.47	0.45	0.45	0.44	0.54	0.48	0.53	0.46	0.50
9	0.47	0.31	0.32	0.39	0.40	0.36	0.37	0.34	0.29	0.35	0.35
10	2.92	2.85	2.77	2.77	2.80	2.87	2.89	2.85	2.79	2.84	2.81
11	1.65	1.58	1.46	1.54	1.52	1.62	1.45	1.59	1.47	1.58	1.47
12	1.48	1.24	1.31	1.34	1.36	1.42	1.38	1.25	1.30	1.31	1.34
13	3.49	3.56	3.55	3.68	3.55	3.78	3.78	3.54	3.52	3.64	3.60
14	2.03	1.89	1.93	1.96	1.95	2.02	1.86	1.86	1.88	1.93	1.91
15	2.26	2.26	2.20	2.30	2.27	2.39	2.32	2.25	2.22	2.30	2.25
16	3.31	3.42	3.44	3.46	3.44	3.53	3.64	3.40	3.38	3.45	3.47
17	3.49	3.40	3.35	3.64	3.61	3.74	3.70	3.46	3.53	3.56	3.55
18	5.54	5.60	5.64	5.64	5.54	5.68	5.66	5.51	5.54	5.61	5.59
19	3.10	2.92	2.99	3.01	2.99	3.13	3.30	2.91	3.02	2.99	3.08
20	1.87	1.61	1.57	1.62	1.60	1.71	1.65	1.65	1.68	1.65	1.63
Average:	2.21	2.13	2.11	2.17	2.15	2.22	2.22	2.17	2.16	2.17	2.16

Table B-2. Difference Between Monitor and Method 106 - First Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
1	2.72	-0.07	-0.14	-0.02	-0.16	-0.04	-0.06	0.09	0.02	-0.01	-0.09
2	3.20	-0.26	-0.27	-0.20	-0.17	-0.23	-0.19	-0.11	-0.12	-0.20	-0.19
3	2.53	-0.03	-0.06	0.05	0.05	0.05	0.08	0.18	0.14	0.06	0.05
4	1.59	-0.13	-0.02	-0.07	-0.01	-0.05	0.01	0.04	0.07	-0.05	0.01
5	0.72	-0.18	-0.20	-0.18	-0.21	-0.13	-0.16	-0.06	-0.17	-0.14	-0.18
6	0.78	-0.05	-0.03	-0.05	-0.01	0.00	0.03	0.03	0.06	-0.02	0.01
7	0.60	-0.01	-0.12	-0.07	-0.12	0.03	-0.06	0.04	-0.04	0.00	-0.08
8	0.45	0.02	0.02	0.00	0.00	-0.01	0.09	0.03	0.08	0.01	0.05
9	0.47	-0.16	-0.15	-0.08	-0.08	-0.11	-0.10	-0.13	-0.18	-0.12	-0.12
10	2.92	-0.07	-0.15	-0.15	-0.12	-0.05	-0.03	-0.07	-0.13	-0.08	-0.11
11	1.65	-0.07	-0.19	-0.12	-0.13	-0.03	-0.20	-0.06	-0.18	-0.07	-0.18
12	1.48	-0.24	-0.17	-0.14	-0.12	-0.06	-0.10	-0.23	-0.18	-0.17	-0.14
13	3.49	0.07	0.06	0.19	0.06	0.29	0.29	0.05	0.03	0.15	0.11
14	2.03	-0.14	-0.10	-0.07	-0.08	-0.01	-0.17	-0.17	-0.15	-0.10	-0.12
15	2.26	0.00	-0.06	0.04	0.01	0.13	0.06	-0.01	-0.04	0.04	-0.01
16	3.31	0.11	0.13	0.15	0.13	0.22	0.33	0.09	0.07	0.14	0.16
17	3.49	-0.09	-0.14	0.15	0.12	0.25	0.21	-0.03	0.04	0.07	0.06
18	5.54	0.06	0.10	0.10	0.00	0.14	0.12	-0.03	0.00	0.07	0.05
19	3.10	-0.18	-0.11	-0.09	-0.11	0.03	0.20	-0.20	-0.08	-0.11	-0.02
20	1.87	-0.26	-0.30	-0.25	-0.27	-0.16	-0.22	-0.22	-0.19	-0.22	-0.24
Average:	2.21	-0.08	-0.10	-0.04	-0.06	0.01	0.01	-0.04	-0.05	-0.04	-0.05

Table B-3. Difference Between Monitor and Method 106 - First Test Series.

Run #	Method 106 (ppm)	PD-mon (%)	PD-bag (%)	FD-mon (%)	FD-bag (%)	PA-mon (%)	PA-bag (%)	FA-mon (%)	FA-bag (%)	Ave.-mon (%)	Ave.-bag (%)
1	2.72	-2.7	-5.2	-0.8	-6.0	-1.4	-2.2	3.1	0.8	-0.4	-3.2
2	3.20	-8.0	-8.6	-6.2	-5.4	-7.3	-6.0	-3.3	-3.8	-6.2	-5.9
3	2.53	-1.2	-2.3	2.0	1.9	1.8	3.0	7.2	5.5	2.4	2.0
4	1.59	-7.9	-1.4	-4.3	-0.5	-3.0	0.6	2.2	4.6	-3.3	0.8
5	0.72	-25.6	-27.4	-25.6	-29.0	-18.6	-21.7	-8.1	-23.8	-19.4	-25.5
6	0.78	-6.0	-3.5	-6.9	-0.9	0.3	3.6	4.0	7.2	-2.2	1.6
7	0.60	-1.5	-19.2	-12.2	-20.0	5.0	-9.8	6.3	-6.3	-0.6	-13.8
8	0.45	5.3	5.3	0.0	-0.2	-1.3	20.7	6.2	18.2	2.6	11.0
9	0.47	-34.0	-31.7	-16.6	-16.0	-23.8	-20.4	-28.5	-38.1	-25.7	-26.5
10	2.92	-2.5	-5.3	-5.1	-4.0	-1.6	-0.9	-2.3	-4.5	-2.9	-3.7
11	1.65	-4.1	-11.6	-7.0	-7.6	-2.0	-12.1	-3.8	-11.2	-4.2	-10.6
12	1.48	-16.4	-11.8	-9.2	-7.8	-3.9	-6.9	-15.3	-12.2	-11.2	-9.7
13	3.49	1.9	1.6	5.3	1.7	8.4	8.4	1.3	0.9	4.2	3.1
14	2.03	-7.0	-4.7	-3.3	-3.7	-0.5	-8.3	-8.3	-7.2	-4.8	-6.0
15	2.26	0.0	-2.7	1.7	0.4	5.8	2.6	-0.4	-1.8	1.8	-0.3
16	3.31	3.3	3.9	4.6	3.9	6.6	9.9	2.6	2.1	4.3	5.0
17	3.49	-2.6	-4.1	4.3	3.3	7.1	6.1	-0.9	1.2	2.0	1.6
18	5.54	1.1	1.7	1.7	0.0	2.6	2.2	-0.5	0.0	1.2	1.0
19	3.10	-5.8	-3.5	-2.9	-3.4	0.9	6.5	-6.3	-2.5	-3.5	-0.7
20	1.87	-14.1	-16.1	-13.4	-14.2	-8.8	-11.6	-11.9	-10.2	-12.0	-13.0
Average:	2.21	-6.4	-7.3	-4.7	-5.4	-1.7	-1.8	-2.8	-4.0	-3.9	-4.6

Table B-4. Average Readings for each Run - Second Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
21	6.78	6.40	6.56	6.18	6.39	5.80	6.44	6.70	6.72	6.27	6.53
22	4.48	4.35	4.39	4.42	4.30	4.62	5.09	4.66	4.57	4.51	4.59
23	4.09	4.12	3.77	4.34	4.30	4.42	4.22	4.35	4.36	4.30	4.16
24	5.31	5.59	5.17	5.76	5.43	5.85	5.44	5.67	5.58	5.72	5.40
25	7.32	7.94	7.92	8.83	7.81	8.73	7.79	8.06	7.92	8.39	7.86
26	5.48	6.20	6.09	6.07	5.77	6.04	6.17	6.31	5.96	6.15	6.00
27	5.68	4.52	5.34	7.06	5.61	6.08	5.06	4.86	5.58	5.63	5.40
28	19.46	16.10	20.04	20.54	20.02	11.48	11.73	12.82	15.18	15.23	16.74
29	5.01	4.51	4.95	5.12	5.01	5.17	5.51	5.04	4.99	4.96	5.12
30	4.73	4.62	4.32	4.73	4.74	4.85	4.55	4.96	4.84	4.79	4.61
31	3.40	3.17	3.11	3.35	3.43	3.49	3.27	3.59	3.51	3.40	3.33
32	6.78	8.15	6.20	7.56	6.19	7.24	6.27	8.16	6.55	7.77	6.30
33	4.63	4.63	4.74	4.57	4.62	4.65	4.72	4.98	4.89	4.71	4.74
34	4.08	3.93	3.96	3.93	3.96	4.19	4.13	4.26	4.28	4.08	4.08
35	19.60	20.12	20.69	20.80	20.02	11.95	11.95	15.35	15.35	17.05	17.00
36	19.34	15.95	19.63	18.91	19.55	11.95	11.95	13.71	15.35	15.13	16.62
37	2.83	2.64	2.83	2.87	2.71	2.97	2.71	2.99	3.06	2.87	2.83
38	3.56	3.61	3.80	3.78	3.62	3.89	3.79	3.84	3.87	3.78	3.77
39	3.43	3.31	3.91	3.41	3.45	3.58	3.75	3.58	3.66	3.47	3.69
40	6.21	6.47	6.45	6.60	6.52	6.72	6.42	6.56	6.43	6.59	6.45
Average:	7.11	6.81	7.19	7.44	7.17	6.18	6.05	6.52	6.63	6.74	6.76

Table B-5. Difference Between Monitor and Method 106 - Second Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
21	6.78	-0.38	-0.23	-0.60	-0.39	-0.98	-0.34	-0.08	-0.06	-0.51	-0.25
22	4.48	-0.13	-0.09	-0.06	-0.18	0.14	0.61	0.18	0.09	0.03	0.11
23	4.09	0.03	-0.32	0.25	0.21	0.33	0.13	0.26	0.27	0.21	0.07
24	5.31	0.28	-0.14	0.45	0.12	0.54	0.13	0.36	0.27	0.41	0.09
25	7.32	0.62	0.60	1.51	0.49	*	0.47	0.74	0.60	0.96	0.54
26	5.48	0.72	0.61	0.59	0.29	0.56	0.69	0.83	0.48	0.67	0.52
27	5.68	-1.17	-0.34	1.38	-0.07	*	-0.62	*	-0.10	0.11	-0.28
28	19.46	-3.36	0.58	1.08	0.56	*	*	*	*	-1.14	0.57
29	5.01	-0.50	-0.06	0.11	0.00	0.16	0.50	0.03	-0.02	-0.05	0.11
30	4.73	-0.11	-0.41	0.00	0.01	0.12	-0.18	0.23	0.11	0.06	-0.12
31	3.40	-0.23	-0.29	-0.05	0.03	0.09	-0.14	0.19	0.11	0.00	-0.07
32	6.78	1.37	-0.58	0.78	-0.59	0.46	-0.51	1.38	-0.23	0.99	-0.48
33	4.63	0.00	0.11	-0.07	-0.01	0.02	0.09	0.35	0.26	0.08	0.11
34	4.08	-0.15	-0.12	-0.15	-0.12	0.11	0.05	0.18	0.20	-0.01	0.00
35	19.60	0.52	1.09	1.20	0.42	*	*	*	*	0.86	0.76
36	19.34	-3.39	0.29	-0.43	0.21	*	*	*	*	-1.91	0.25
37	2.83	-0.20	0.00	0.04	-0.12	0.14	-0.12	0.16	0.23	0.04	0.00
38	3.56	0.05	0.24	0.22	0.06	0.33	0.23	0.28	0.31	0.22	0.21
39	3.43	-0.12	0.48	-0.03	0.02	0.15	0.32	0.15	0.23	0.04	0.26
40	6.21	0.26	0.24	0.39	0.31	0.51	0.21	0.35	0.22	0.38	0.24
Average:	7.11	-0.30	0.08	0.33	0.06	0.18	0.09	0.35	0.17	0.14	0.10

* - Readings were over-range or fragmentary during run.

Table B-6. Difference Between Monitor and Method 106 - Second Test Series.

Run #	Method 106 (ppm)	PD-mon (%)	PD-bag (%)	FD-mon (%)	FD-bag (%)	PA-mon (%)	PA-bag (%)	FA-mon (%)	FA-bag (%)	Ave.-mon (%)	Ave.-bag (%)
21	6.78	-5.6	-3.3	-8.8	-5.7	-14.5	-5.0	-1.2	-0.9	-7.5	-3.7
22	4.48	-2.9	-2.0	-1.3	-4.1	3.1	13.7	4.0	2.1	0.7	2.4
23	4.09	0.7	-7.7	6.0	5.1	7.9	3.1	6.3	6.5	5.2	1.7
24	5.31	5.3	-2.6	8.5	2.3	10.2	2.4	6.8	5.0	7.7	1.8
25	7.32	8.5	8.2	20.6	6.6	*	6.4	10.0	8.2	13.1	7.4
26	5.48	13.0	11.2	10.8	5.2	10.3	12.5	15.1	8.7	12.3	9.4
27	5.68	-20.5	-6.1	24.3	-1.3	*	-10.9	*	-1.8	1.9	-5.0
28	19.46	-17.3	3.0	5.6	2.9	*	*	*	*	-5.9	2.9
29	5.01	-10.0	-1.2	2.1	0.0	3.2	10.0	0.6	-0.4	-1.0	2.1
30	4.73	-2.3	-8.7	-0.1	0.3	2.6	-3.8	4.8	2.3	1.2	-2.5
31	3.40	-6.9	-8.6	-1.4	0.8	2.7	-4.0	5.6	3.1	0.0	-2.2
32	6.78	20.1	-8.6	11.4	-8.7	6.8	-7.5	20.3	-3.3	14.7	-7.0
33	4.63	0.0	2.3	-1.4	-0.2	0.4	2.0	7.6	5.7	1.6	2.4
34	4.08	-3.8	-3.0	-3.7	-2.9	2.7	1.2	4.3	5.0	-0.1	0.1
35	19.60	2.6	5.6	6.1	2.2	*	*	*	*	4.4	3.9
36	19.34	-17.5	1.5	-2.2	1.1	*	*	*	*	-9.9	1.3
37	2.83	-6.9	0.0	1.3	-4.1	4.9	-4.3	5.7	8.0	1.3	-0.1
38	3.56	1.4	6.8	6.0	1.7	9.1	6.4	7.9	8.7	6.1	5.9
39	3.43	-3.5	13.9	-0.7	0.7	4.5	9.2	4.5	6.6	1.2	7.6
40	6.21	4.1	3.8	6.2	5.0	8.3	3.3	5.7	3.5	6.1	3.9
Average:	7.11	-2.1	0.2	4.5	0.3	4.1	2.0	6.8	3.9	3.3	1.6

* - Readings were over-range or fragmentary during run.

Table B-7. Average Readings for each Run - Third Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
41	7.07	8.24	7.52	6.98	8.26	7.54	7.77	7.72	7.64	7.62	7.80
42	1.48	1.98	1.33	1.50	1.37	1.66	1.64	1.81	1.69	1.74	1.51
43	0.45	0.52	0.41	0.44	0.35	0.75	0.56	0.71	0.67	0.60	0.50
44	9.95	10.13	12.46	21.55	12.24	14.55	12.79	13.13	12.02	14.84	12.38
45	3.04	3.72	3.03	2.81	3.66	3.43	4.00	4.52	3.48	3.62	3.54
46	1.24	1.25	0.84	1.21	1.04	1.67	1.58	1.75	1.32	1.47	1.19
47	0.63	0.52	0.36	0.49	0.26	0.88	0.61	0.71	0.55	0.65	0.44
48	0.36	0.20	0.12	0.17	0.09	0.37	0.47	0.38	0.39	0.28	0.27
49	5.42	6.04	6.11	6.41	6.33	6.40	6.25	6.21	6.22	6.26	6.23
50	37.38	15.25	32.10	21.65	37.62	12.14	13.40	11.24	17.13	15.07	25.06
51	6.45	7.66	7.33	7.68	7.71	5.82	7.62	7.46	7.39	7.15	7.51
52	1.81	1.71	1.87	1.64	1.59	1.89	2.12	1.94	2.17	1.79	1.94
53	16.87	0.49	19.50	4.69	19.09	1.91	12.72	0.81	16.46	1.97	16.94
54	0.59	0.34	0.45	0.33	0.39	0.55	0.68	0.53	0.62	0.44	0.54
55	0.22	0.18	0.17	0.14	0.13	0.29	0.38	0.33	0.33	0.24	0.25
56	8.98	7.86	10.25	6.72	9.82	6.57	10.02	5.23	9.98	6.59	10.02
57	0.92	0.92	0.73	0.87	0.55	1.03	0.99	1.14	1.17	0.99	0.86
58	3.12	3.56	3.48	1.97	3.00	2.22	3.65	3.40	3.57	2.79	3.43
59	0.34	0.18	0.19	0.29	0.21	0.30	0.27	0.45	0.49	0.31	0.29
60	2.68	1.35	2.82	3.52	2.66	2.85	2.99	1.64	3.04	2.34	2.88
Average:	5.45	3.60	5.55	4.55	5.82	3.64	4.53	3.55	4.82	3.84	5.18

Table B-8. Differences Between Monitor and Method 106 - Third Test Series.

Run #	Method 106 (ppm)	PD-mon (ppm)	PD-bag (ppm)	FD-mon (ppm)	FD-bag (ppm)	PA-mon (ppm)	PA-bag (ppm)	FA-mon (ppm)	FA-bag (ppm)	Ave.-mon (ppm)	Ave.-bag (ppm)
41	7.07										
42	1.48	1.17	0.45	-0.09	1.19	0.47	0.70	0.65	0.57	0.55	0.73
43	0.45	0.50	-0.15	0.02	-0.11	0.18	0.16	0.33	0.21	0.26	0.03
44	9.95	0.07	-0.04	-0.01	-0.10	0.30	0.11	0.26	0.22	0.15	0.05
45	3.04	*	2.51	*	2.29	*	2.84	*	2.07	*	2.43
46	1.24	*	-0.02	*	0.62	*	0.96	*	0.44	*	0.50
47	0.63	0.01	-0.40	-0.03	-0.20	0.43	0.34	0.51	0.08	0.23	-0.05
48	0.36	-0.11	-0.27	-0.15	-0.37	0.25	-0.02	0.08	-0.09	0.02	-0.19
49	5.42	-0.16	-0.24	-0.19	-0.27	0.01	0.11	0.02	0.03	-0.08	-0.09
50	37.38	0.62	0.69	0.99	0.91	0.98	0.83	0.79	0.80	0.84	0.81
51	6.45	*	*	*	0.24	*	*	*	*	*	0.24
52	1.81	1.21	0.88	1.23	1.26	*	1.17	*	0.94	1.22	1.06
53	16.87	-0.10	0.06	-0.17	-0.22	0.08	0.31	0.13	0.36	-0.02	0.13
54	0.59	*	2.63	*	2.22	*	*	*	*	*	2.43
55	0.22	-0.25	-0.14	-0.26	-0.20	-0.04	0.09	-0.06	0.03	-0.15	-0.05
56	8.98	-0.05	-0.05	-0.08	-0.09	0.07	0.16	0.11	0.11	0.02	0.03
57	0.92	*	1.27	*	0.84	*	1.04	*	1.00	*	1.04
58	3.12	-0.01	-0.19	-0.06	-0.37	0.11	0.07	0.22	0.25	0.07	-0.06
59	0.34	*	0.36	*	-0.12	*	0.53	*	0.45	*	0.31
60	2.68	-0.16	-0.15	-0.05	-0.13	-0.04	-0.07	0.11	0.15	-0.03	-0.05
		-1.33	0.14	0.84	-0.02	*	0.31	-1.04	0.36	-0.51	0.20
Average:	5.45	0.10	0.39	0.14	0.37	0.23	0.54	0.16	0.44	0.16	0.43

* - Readings were over-range or fragmentary during run.

Table B-9. Differences Between Monitor and Method 106 - Third Test Series.

Run #	Method 106 (ppm)	PD-mon (%)	PD-bag (%)	FD-mon (%)	FD-bag (%)	PA-mon (%)	PA-bag (%)	FA-mon (%)	FA-bag (%)	Ave.-mon (%)	Ave.-bag (%)
41	7.07	16.6	6.3	-1.3	16.8	6.6	9.9	9.2	8.1	7.7	10.3
42	1.48	33.4	-10.2	1.0	-7.2	12.4	10.9	22.4	13.9	17.3	1.9
43	0.45	14.9	-8.9	-1.8	-21.3	66.2	24.7	57.1	49.3	34.1	10.9
44	9.95	*	25.2	*	23.0	*	28.6	*	20.8	*	24.4
45	3.04	*	-0.5	*	20.3	*	31.4	*	14.5	*	16.4
46	1.24	0.6	-32.3	-2.3	-16.4	34.4	27.1	41.0	6.8	18.4	-3.7
47	0.63	-18.1	-42.9	-23.0	-59.4	39.4	-3.2	12.4	-13.5	2.7	-29.7
48	0.36	-45.6	-65.8	-53.3	-76.1	3.9	31.4	4.7	6.9	-22.6	-25.9
49	5.42	11.4	12.7	18.3	16.7	18.0	15.4	14.5	14.8	15.6	14.9
50	37.38	*	*	*	0.6	*	*	*	*	*	0.6
51	6.45	18.8	13.7	19.0	19.5	*	18.2	*	14.6	18.9	16.5
52	1.81	-5.7	3.1	-9.2	-11.9	4.5	17.1	6.9	19.7	-0.9	7.0
53	16.87	*	15.6	*	13.1	*	*	*	*	*	14.4
54	0.59	-43.1	-23.6	-44.1	-33.9	-6.4	15.6	-10.5	5.4	-26.0	-9.1
55	0.22	-20.5	-22.7	-35.0	-42.3	33.6	71.4	49.5	48.2	6.9	13.6
56	8.98	*	14.1	*	9.4	*	11.6	*	11.2	*	11.6
57	0.92	-0.5	-21.1	-6.0	-40.0	11.5	7.6	23.9	27.2	7.2	-6.6
58	3.12	*	11.6	*	-3.9	*	17.0	*	14.5	*	9.8
59	0.34	-46.5	-44.4	-14.4	-39.1	-11.8	-21.2	32.4	42.9	-10.1	-15.4
60	2.68	-49.5	5.1	31.3	-0.6	*	11.5	-39.0	13.4	-19.1	7.4
Average:	5.45	-9.5	-8.7	-8.6	-11.6	17.7	18.1	17.3	17.7	4.2	3.9

* - Readings were over-range or fragmentary during run.

APPENDIX C

DEFINITION OF TERMS

Standard Deviation (σ); Section 3.2,

$$\sigma = \sqrt{\frac{\sum_1^n (X_i - \bar{X})}{n-1}}$$

where n is the number of observations.

X_i is the ith observation.

$\bar{X}$ is the average.

Average, Sections 3.2; 3.3.2

$$\bar{X} = \frac{\sum_1^n X_i}{n}$$

Relative standard deviation; Section 3.2,

$$\text{r.s.d. } (\%) = \frac{\sigma}{\bar{X}} \times 100$$

Bias (relative error); Sections 3.3.1, 3.3.2, 4.1

$\bar{X}_{(FD,PD,PA)} - \bar{X}_{FA}$

Section 3.3.2 substitutes $\bar{X}_{M106}$ for $\bar{X}_{FA}$ where $\bar{X}_{106}$ is the average concentration measured by Method 106.

Difference standard deviation (precision); Section 3.3.1,

$$\sigma = \sqrt{\frac{\sum_1^n (X_i - Z_i)}{n-1}}$$

where X_i is the ith reading from the FD (or PD) channel.

Z_i is the ith reading from the PA (or FA) channel.

% Recovery; Section 3.3.1;

$$\% \text{ Recovery} = \frac{\text{number of complete quads recorded}}{\text{Theoretical number of quads during 23 hr}} \times 100$$

% outliers, overrange, usable data also use the above equation substituting the number of quads (outliers, overrange, or usable) and the theoretical number of quads obtainable.

Zero drift; Section 3.3.1,

$$\text{drift} = Z_i - Z_o$$

where Z_i is the LLSQ calibration intercept for day i.

Z_o is the LLSQ calibration intercept for the last manual calibration adjustment.

Slope drift; Section 3.3.1

$$\text{Drift } (\%) = \frac{S_i - S_o}{S_o} \times 100$$

where S_i is the LLSQ calibration slope for day i.

S_o is the LLSQ calibration slope for the last manual calibration adjustment.